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Has the Euro Affected the Choice of Invoicing Currency?*

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Abstract

We present a new approach to study empirically the effect of the introduction of the euro on currency invoicing. Our approach uses a compositional multinomial logit model, in which currency choice depends on the characteristics of both the currency and the country. We use unique quarterly panel data of Norwegian imports from OECD countries for the 1996–2006 period. One of the key findings is that the eurozone countries in trade with Norway have substantially increased their share of home currency invoicing after the introduction of the euro. In addition, the euro as a vehicle currency has overtaken the role of the US dollar in Norwegian imports. The econometric analysis shows a significant effect of euro introduction above and beyond the determinants of currency invoicing (i.e., inflation rate, inflation volatility, foreign exchange market size, and product composition). However, the rise in producer currency invoicing by eurozone countries is primarily caused by a drop in inflation volatility.

JEL codes: F14, F15, F31, F33, F36, E31, C25

Keywords: euro, invoicing currency, exchange rate risk, inflation, inflation risk, vehicle currencies, compositional multinomial logit

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1 Introduction

Currency invoicing of international goods trade has interested academics and policy makers as early as the 1970s when the Bretton Woods system of fixed but adjustable exchange rates collapsed and the principle trading countries in the world moved to flexible exchange rates. The introduction of the euro in non-cash form (i.e., electronic transfers, banking, etcetera) on January 1, 1999 and in cash form on January 1, 2002[1] has given a renewed impetus to the invoicing literature.[2] The introduction of the euro is believed to have had a substantial impact on traders' choice of invoicing currency. More specifically, the euro would boost home currency invoicing by eurozone countries and euro use by countries trading with the eurozone members.[3] So far, only a few empirical studies have analyzed the determinants of currency invoicing, but none of them measure the effects of the euro on currency groups as well as individual currencies during the two stages of euro introduction. This paper therefore empirically investigates whether the euro has affected invoicing practices across countries.

The objective of this study is to empirically assess the impact of the euro on the choice of invoicing currency using a unique invoicing dataset for Norway. The data (measured at a quarterly frequency) consist of the value of Norwegian goods imports broken down by country and currency for the period 1996–2006. Although the overall dataset covers all countries, the econometric analysis includes only 29 OECD countries, roughly capturing 85 percent of Norwegian trade. The invoicing data used in this study span the introduction of the euro, the transition period 1999–2001 (when both the euro and legacy currencies[4] could be used in trade), and a sufficiently large post-transition period. We have chosen Norway because it is not part of the eurozone, which allows the study of the effect of the euro on partner currency use in Norwegian trade with eurozone countries and on vehicle currency invoicing outside

[1]The euro was introduced on January 1, 1999 in Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. Greece joined on January 1, 2001, bringing the total number of European Union member states adopting the euro (the so-called eurozone) to 12 countries. Nowadays, the eurozone consists of 16 countries.

[2]The "New Open Economy Macroeconomics" literature also contributed to this revival. See Section 2.

[3]Bacchetta and Van Wincoop (2005) present a theoretical analysis, whereas Kamps (2006) and Goldberg and Tille (2008) empirically assess the determinants of countries' euro invoicing share in a cross-country setting. See Section 2 for a discussion of the invoicing literature.

[4]Legacy currencies are the currencies of the eurozone members that ceased to exist at the end of the transition period toward euro introduction.

the eurozone.[5] We use dummies for the year of introduction of the euro and the use of the euro during the transition period to investigate whether invoicing practices are affected by the euro. In addition, we analyze whether the euro has caused a substantial shift in invoicing patterns by employing Andrews's (1993) structural break test for nonlinear models.

We employ a compositional multinomial logit approach that weights the probability of choosing a particular currency by its respective currency share. This approach is appropriate because we have compositional data, that is, the currency shares lie in the closed unit interval $[0, 1]$, add up to unity for a particular country at one point in time, and are correlated. Our analysis incorporates the characteristics of 31 currencies and thus goes beyond just characterizing the share of the partner currency or the share of a single currency (e.g., the euro). We employ both fixed effects and pooled compositional multinomial models, where the former specification controls for unobserved heterogeneity across countries. To allow for a proper inference of the variables' magnitudes, we derive average marginal effects. Because there seems to be a strong inertial bias in favor of using whatever currency has been used in the past (so-called hysteresis), we also use a dynamic model that includes past currency shares.

So far, the empirical invoicing literature has only used explanatory variables related to the partner countries in trade (i.e., country-specific variables). This study introduces a new approach that relates covariates to the currencies (i.e., currency-specific variables), that is, we propose the *conditional* compositional multinomial logit (CCML).[6] More specifically, the CCML approach makes it possible to relate traders' invoicing motives directly to the currency attributes, that is, a euro dummy, a euro transition dummy, exchange rate volatility of the chosen currency to the local currency (Norwegian Krone), exchange rate volatility of the chosen currency with respect to the partner currency, the depth of the currency's foreign exchange market, and the past currency share. Currency-specific variables contain information that reflects more realistically the trader's decision problem at hand. However, to make inference practical, we group the 31 currencies in three groups—i.e., producer currency

[5] A "vehicle" or "third" currency is neither the currency of the exporter nor that of the importer in a trade transaction. We will use the terminology "vehicle currency" and "third currency" interchangeably.

[6] The discrete choice literature usually refers to the country-specific and currency-specific regressors distinction as "alternative-invariant" and "alternative-varying" regressors, respectively.

invoicing (PCI), local currency invoicing (LCI), and vehicle currency invoicing (VCI)—and identify them broadly. In our study, PCI denotes invoicing in the home currency of the exporter (partner country), whereas LCI refers to invoicing in the currency of the country where the exporter's goods are sold (Norway). Besides these methodological extensions and the measurement of the euro effect, the paper also contributes to the invoicing literature more generally by considering a broader set of covariates. New variables of interest such as inflation volatility, the depth of the foreign exchange market, and the degree of differentiation of the partner country's export package are considered.

The descriptive analysis of the data shows a change in Norwegian invoicing patterns during the period of euro introduction. Norway's trading partners participating in the eurozone use their own currency (i.e., the euro) more frequently than before the introduction of the euro. In addition, the euro is chosen more often as a vehicle (or third) currency than the US dollar. The econometric analysis shows that above and beyond the control variables, the introduction of the euro has had a significant positive effect on the share of producer currency invoicing by eurozone countries. Conditional on key fundamental variables, the producer currency shares of Mediterranean countries in the eurozone benefited the most from euro adoption. The analysis is also the first to show the quantitative significance of—the much hypothesized—inflation volatility variable. The rise in invoicing in producer currencies by eurozone countries is primarily caused by a drop in inflation volatility. Three other significant explanatory variables are identified: the inflation rate, the size of the foreign exchange market, and the degree of product differentiation. Finally, our model is stable across the time period of euro introduction. The structural break tests finds a peak of the test statistic around the time of introduction of the euro, but it does not exceed the 10 percent significance level.

This paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the Norwegian invoicing data. Section 4 discusses the econometric methodology. Section 5 presents the results on the euro effect and the determinants of invoicing currency choice more generally. In addition, it investigates a possible structural break in invoicing patterns related to the euro. Finally, Section 6 concludes.

2 Related Literature

The theoretical literature on the invoicing effects of euro introduction and monetary integration more generally is rather small. Bacchetta and Van Wincoop's (2005) two-country general equilibrium model on invoicing currency choice is a notable exception. They hypothesize that if a set of countries form a monetary union they are more likely to invoice in the union's currency. Intuitively, if multiple countries adopt the same currency, the market share that matters is that of the entire currency union, not that of individual countries. The study of Devereux, Engel, and Storgaard (2004) deals with a potential indirect effect of monetary integration. They argue that exporters and importers will generally prefer to set prices in the currency of the country with a more stable monetary policy, as given by the variance of the relative money supplies.

The studies of Devereux, Engel, and Storgaard (2004) and Bacchetta and Van Wincoop (2005) build on the New Open Economy Macroeconomics literature, which is primarily initiated by the work of Obstfeld and Rogoff (1995), also known as the Redux model. Key features of this research line are monopolistic competition and sticky nominal prices pre-set in a particular currency. An important issue in this literature is in which currency prices are assumed to be sticky. The Redux model assumes producer currency pricing (PCP), that is, exporters set prices in their home currency. Accordingly, there is complete exchange rate pass-through of prices of imported goods to prices of domestic goods, ensuring that purchasing power parity holds at all times. However, Betts and Devereux (2000) show that the expenditure-switching effect of a nominal exchange rate change under PCP breaks down if firms engage in local currency pricing (LCP), that is, exporters pre-set prices and invoice in the importer's currency.[7] Devereux, Engel, and Storgaard (2004) and Bacchetta and Van Wincoop (2005) are some of the few studies to endogenize the PCP/LCP share.

Little is known empirically about the determinants of invoicing, let alone the effect of currency unions on invoicing patterns.[8] A few econometric studies focus on invoicing determinants—using data for a single country—without touching upon currency union issues;

[7] Krugman (1987) was one of the first authors to point out that foreign firms price locally.

[8] The limited number of studies no doubt reflects the considerable confidentiality with which the invoicing data are treated by central banks and customs offices.

that is, Donnenfeld and Haug (2003) for Canada, Wilander (2006) for Sweden, Donnenfeld and Haug (2008) for the United States, and Ligthart and Da Silva (2007) for the Netherlands. Wilander (2006) uses data on individual transactions, whereas the others focus on aggregate currency shares. Most of these studies show that a country's market power—measured in terms of a country's world export share—leads to increased invoicing of its home currency. In addition, Ligthart and Da Silva (2007) find home currency invoicing to be positively affected by the rate of inflation in the partner country and negatively affected by the degree of development of the partner country's banking sector. They also find that European Union countries invoice less in vehicle currencies.

Kamps (2006) and Goldberg and Tille (2008) empirically assess the effect of euro introduction on currency invoicing. Both studies use aggregate cross-country data for currency shares as the dependent variable, but do not take into account that the invoicing shares should be viewed as a system of equations.[9] Because the shares add up to unity, an increase in one share necessarily implies a drop in other currency shares. Kamps (2006) regresses both the euro and US dollar share on a set of explanatory variables. She additionally analyzes—in a separate regression equation—the home currency share in exports and imports. Her analysis covers 42 countries and uses annual data for the 1994–2004 period. Kamps finds that a country being a member of the European Union (EU) or an EU accession candidate plays a decisive role in the choice of the euro as invoicing currency. In addition, the share of euro invoicing rises if a country pegs its currency to the euro, has a larger share of differentiated products in exports, and trades more with the eurozone. Countries' US dollar share in invoicing is negatively affected by their membership of the eurozone.

Goldberg and Tille (2008) use the invoicing share of the US dollar and the euro as the respective dependent variables. Their analysis consists of 24 countries (including among others nine EU accession countries, Australia, the United States, and Japan) and uses annual observations for 1996–2003 and thus covers only one year after the full-blown introduction of the euro. Goldberg and Tille (2008) find that the US dollar is predominantly used in countries'

[9] Both Kamps (2006) and Goldberg and Tille (2008) employ very unbalanced data sets, reflecting the scarcity of invoicing data at the cross-country level. Some countries cover the whole time period, whereas only individual years are observed for other countries.

invoicing of goods trade with the United States and in the setting of prices of goods traded on organized exchanges. They show furthermore that the euro is primarily employed as an invoicing currency by countries trading a substantial share of their goods with the eurozone.

3 Data and Descriptive Analysis

The data used in this study have been collected by the Norwegian customs office. The Norwegian customs law requires traders to report all goods trade transactions of a value exceeding NOK 10,000 (euro 1,127). A small fraction of trade (less than 3 percent) is censored; it does not exceed 5 percent in trade with any partner country. The customs office has provided the aggregate values of Norwegian goods imports broken down by currency and country of the trading partner for the 1996–2006 period. Because of confidentiality concerns, single transactions are not made available. In addition, transactions in the oil and shipping sector—in which just a few large firms are active—are excluded from the reported data. In the following, we assume that the currency of payment (as recorded in the data) in any period is equal to the currency of invoicing (which we cannot observe). Friberg and Wilander (2008) point out that in more than 90 percent of the cases the two coincide.

We include 29 OECD countries in our analysis. The total of value of Norwegian imports from OECD countries is on average 85 percent (Table A.1), representing a large share of Norwegian trade. The share of producer currencies (PCI) varies substantially across both OECD and non-OECD countries. The home currency share of Norway's most important trading partner (Sweden) amounts to 45.4 percent, whereas that of its second most important trading partner (Germany) is 71.6 percent. Although China is ranked as Norway's eighth largest trading partner, the share of the Renminbi is negligible. More generally, many of the non-OECD countries have a negligible or zero share of PCI.

Panel (a) of Figure 1 shows the currency share of every partner country equally weighted, whereas Panel (b) gives the trade-weighted currency shares.[10] The introduction of the euro

[10] Norway's five biggest OECD trading partners make up more than 50 percent of its imports. To preclude that the invoicing pattern of the "big five" will overshadow the invoicing of Norway's trade with smaller trading partners, we calculate equally weighted currency shares by averaging over the bilateral currency shares. The latter are used in the econometric analysis of Section 4.

as a virtual currency in 1999 is indicated by the first dotted vertical line, whereas the second dotted vertical line depicts the date of introduction of the euro in cash transactions in 2002 (which marked the abolition of the national currencies of the EU member states). At the aggregate level, the invoicing shares remain stable despite the introduction of the euro. Panel (a) of the figure shows a small increase in the use of producer (or partner) currencies (the dashed line) and a slight drop in the use of the Norwegian Krone (the solid line).

By focusing only on countries in the eurozone [Panels (c)–(d) of Figure 1], we can see that there have been some substantial changes after the introduction of the euro. Panel (c) shows that before the introduction of the euro imports in the eurozone (equally weighted) are mainly invoiced in the Norwegian Krone. Indeed, we can see that the share of producer currencies (30 percent) is only slightly above that of vehicle currencies. The Norwegian Krone makes up 40 percent. This invoicing pattern defies "Grassman's law," which says that trade is mainly invoiced in the currency of the exporter.[11] After the introduction of the euro in cash form, however, the share of partner currencies substantially rises and becomes dominant. During transition, the euro share (the dashed dotted line) gradually increases, whereas the share of the eurozone legacy currencies slowly drops. Panel (d) also reveals a substantial rise in the trade-weighted currency share of the eurozone countries, although it is less pronounced than under equally-weighted currency shares.

Have there been changes in the invoicing pattern with respect to vehicle currencies? Panel (a) of Figure 2 shows that the legacy currencies of the eurozone countries start off in 1996 at 32 percent and the US dollar at about 53 percent. The category "other vehicle currencies" forms on the order of 15 percent of all vehicle currencies. During the transition period, the euro slowly replaces the US dollar. In the middle of the transition period, the euro share—a mixture of eurozone legacy currencies used as third currencies and the euro—slowly overtakes the US dollar. Eventually, the euro share settles at 50 percent while the US dollar hovers at 40 percent. If currency shares are trade weighted, the euro exceeds the US dollar share already at the beginning of the transition period [Panel (b) of Figure 2], increasing its share

[11] Grassman (1973) found in his descriptive analysis of Swedish goods trade that 2/3 of exports to industrialized countries were invoiced in the producer's currency and 1/4 are invoiced in the local currency. Other authors in the 1980s found a similar invoicing pattern, which explains why the literature has coined this pattern Grassman's law.

to 80 percent, whereas the US dollar drops to 20 percent.

Table 1 shows that in 1996 the share of other vehicle currencies (i.e., the non-eurozone currencies excluding the US dollar) consists primarily of the currencies of the two Scandinavian partner countries (i.e., the Swedish Krone and the Danish Krone), together accounting for 12 percent. However, the share of the Pound Sterling—once a major vehicle currency—is very small (2 percent). The German mark is the dominant vehicle currency in the eurozone in 1996 (84 percent of eurozone currencies), followed by the Dutch guilder (5.6 percent). In 2006, the currencies of Scandinavian partner countries (9.8 percent) are still often used next to the euro and US dollar.

Table 2 shows the actual number of vehicle currencies that traders used in invoicing of Norwegian imports from OECD countries across three different time periods. Before the abolition of the eurozone legacy currencies, traders invoiced in up to 23 different vehicle currencies, indicating that not all traders resort to currencies with deep exchange markets. On average, firms in OECD countries employed 16 different vehicle currencies. Despite the role of the US dollar as the world's leading vehicle currency, the United States invoiced its exports to Norway in almost 20 other currencies. Even though 12 national currencies of the eurozone disappeared in 2002, the average number of vehicle currencies used until 2006 only dropped from 16 to 9. As expected, the number of vehicle currencies employed in the invoicing of Norwegian imports from eurozone countries declined on average more than in imports from non-eurozone countries.

4 Empirical Methodology

This section sets out the empirical model that is used to analyze the introduction of the euro on currency invoicing and discusses potential determinants of currency invoicing.

4.1 The Static Model

A common starting point to model an agent's choice among alternatives is the random utility framework. In the context of invoicing, a profit maximizing exporting firm chooses the invoicing currency that gives the highest pay-off.[12] More formally, we define the utility functional of a firm located in partner country $n = 1, ..., N$ choosing currency $j \in \{1, ..., J\}$ in export transaction $i = 1, ..., I$ and in quarter $t = 1, ..., T$ as:

$$U_{ijnt} = \mathbf{d}_n \boldsymbol{\eta} + \mathbf{x}'_{nt} \boldsymbol{\beta} + \mathbf{z}'_{jt} \boldsymbol{\alpha} + \varepsilon_{ijnt}, \tag{1}$$

where $\mathbf{d}_n$ is a $1 \times N$ row vector of dummies equal to one in column n and zero otherwise, $\boldsymbol{\eta}$ measures a country-specific fixed effect, $\mathbf{x}'_{nt}$ is a $1 \times H_x$ row vector of explanatory variables related to country n in each quarter t, $\mathbf{z}'_{jt}$ is a $1 \times H_z$ row vector of explanatory variables related to currency $j = 1, ..., J$ in each quarter t, ε_{ijnt} is the error term, and $\boldsymbol{\eta}$, $\boldsymbol{\beta}$, and $\boldsymbol{\alpha}$ are the coefficient vectors to be estimated.[13] The error term is assumed to be independent across currency choices, countries, and quarters.

We assume that the underlying data generating process of our sample consists of individual import transactions i of value m_{ijnt} (measured in Norwegian Krones). Ideally, we would like to know the probability that an exporter in country n chooses currency j in transaction i at time t, that is,

$$\mathrm{P}_{ijnt} = \mathrm{Prob}[U_{ijnt} > U_{iknt}] \qquad \forall \;\; k \neq j. \tag{2}$$

However, we do not observe every single i, but only have data on the sum of all m_{ijnt}:[14]

$$m_{jnt} = \sum_{i=1}^{I} m_{ijnt}. \tag{3}$$

Instead of using a zero-one identifier to indicate whether a currency is chosen, we calculate J currency shares in Norwegian imports from partner country n. To this end, we divide m_{jnt} by the sum of all imports from country n at time t:

$$s_{jnt} = \frac{m_{jnt}}{\sum_j^J m_{jnt}}. \tag{4}$$

This strategy takes us into the realm of compositional data, where the currency shares have to lie in the closed unit interval $[0, 1]$, satisfy the adding up constraint, and be correlated

[12] We are assuming that the firm in the partner country chooses the currency. Alternatively, we could have assumed that the Norwegian firm is choosing the currency. In practice, the currency choice is the result of Nash bargaining between the two parties. The theoretical ramifications of this is left for further research.

[13] We do not include the characteristics of the trader. See the discussion below.

[14] The inability to differentiate across transaction sizes in aggregate data has been called the ecological inference problem. See King (1997).

(Appendix A.1). With compositional invoicing data, we assume the utility functional (1) to be identical across firms, which modifies to:

$$U_{jnt} = \mathbf{d}_n \boldsymbol{\eta} + \mathbf{x}'_{nt} \boldsymbol{\beta} + \mathbf{z}'_{jt} \boldsymbol{\alpha} + \varepsilon_{jnt}, \tag{5}$$

and yields the probability based on aggregate utility:

$$\begin{aligned} \mathrm{P}_{jnt} &= \mathrm{Prob}[U_{jnt} > U_{knt}] \qquad \forall \;\; k \neq j \\ &= \mathrm{Prob}[s_{jnt} = 1 | \mathbf{x}_{nt}, \mathbf{Z}_t], \end{aligned} \tag{6}$$

which is the probability that Norwegian imports from country n are invoiced in currency j and $\mathbf{Z}_t$ is a $J \times H_z$ matrix, representing all currency choices J and their characteristics $\mathbf{z}_j$.

Our analysis distinguishes up to 31 currencies. We focus only on currencies of OECD countries because no other currencies outside the OECD were actually chosen. Furthermore, it would be computationally demanding to distinguish all currencies in the world. The set of available currencies in the OECD area varies across time (strictly speaking, we should have defined J_t), reflecting euro introduction.[15] After the full-blown introduction of the euro, the number of currencies drops from 31 to 19. To allow the coefficients of the country-specific variables to differ across currency groups $v \in \{1, ..., V\}$, we split the parameter vectors $\boldsymbol{\eta}$ and $\boldsymbol{\beta}$ by currency group and define $\boldsymbol{\eta}_v$ and $\boldsymbol{\beta}_v$. We distinguish three mutually exclusive currency groups: the Norwegian Krone (LCI), the partner currency or currencies (PCI), and vehicle currencies (VCI). From the perspective of a single country, PCI consists of one currency for non-eurozone countries, whereas it includes one or two currencies in the case of eurozone countries (i.e., one of the legacy currencies or the euro or both). The third group (VCI) is composed of a large number of third currencies and varies in composition in each bilateral trading relationship.[16] For purposes of analyzing currency-specific variables, all potential currencies of OECD countries are included in the analysis even though some currencies were

[15] The maximum number of currencies across the three relevant time periods is as follows: (i) 30 currencies of OECD countries and the European Currency Unit (ECU) during the 1996–1998 period; (ii) 30 currencies of OECD countries and the euro during the 1999–2001 period; and (iii) 19 currencies during the 2002–2006 period.

[16] All currency choices, except the Norwegian Krone, can be identified as PCI or VCI depending on Norway's partner country in trade.

never chosen at all (e.g., the Hungarian forint, the Slovak koruna, the Mexican peso, the Turkish lira, and Korean won).

Taking account of the currency groups and assuming a logistic distribution, we can write the probability in (6) as:[17]

$$\mathrm{P}_{jnt} = \frac{\exp(\mathbf{x}'_{nt}\boldsymbol{\beta}_v + \mathbf{z}'_{jt}\boldsymbol{\alpha} + \mathbf{d}_n\boldsymbol{\eta}_v)}{\sum_j^J \exp(\mathbf{x}'_{nt}\boldsymbol{\beta}_v + \mathbf{z}'_{jt}\boldsymbol{\alpha} + \mathbf{d}_n\boldsymbol{\eta}_v)}, \qquad j \neq k, \;\; v \in \{LCI, PCI, VCI\}, \tag{7}$$

where $\boldsymbol{\eta}_v$ and $\boldsymbol{\beta}_v$ are the fixed effects coefficients and the country-specific coefficient vector for currency group v, respectively. This probability-based approach ensures that estimated probabilities satisfy both the adding-up and unit interval constraint. For identification purposes, we need to set the parameter vectors $\boldsymbol{\eta}_v$ and $\boldsymbol{\beta}_v$ to zero for one currency group. We choose $\boldsymbol{\eta}_{LCI} = \boldsymbol{\beta}_{LCI} = 0$, such that

$$\mathrm{P}_{LCInt} = \frac{\exp(\mathbf{z}'_{LCIt}\boldsymbol{\alpha})}{\exp(\mathbf{z}'_{LCIt}\boldsymbol{\alpha}) + \sum_j^{J-1} \exp(\mathbf{x}'_{nt}\boldsymbol{\beta}_v + \mathbf{z}'_{jt}\boldsymbol{\alpha} + \mathbf{d}_n\boldsymbol{\eta}_v)}, \qquad j = v = LCI, \tag{8}$$

and

$$\mathrm{P}_{jnt} = \frac{\exp(\mathbf{x}'_{nt}\boldsymbol{\beta}_v + \mathbf{z}'_{jt}\boldsymbol{\alpha} + \mathbf{d}_n\boldsymbol{\eta}_v)}{\exp(\mathbf{z}'_{LCIt}\boldsymbol{\alpha}) + \sum_j^{J-1} \exp(\mathbf{x}'_{nt}\boldsymbol{\beta}_v + \mathbf{z}'_{jt}\boldsymbol{\alpha} + \mathbf{d}_n\boldsymbol{\eta}_v)} \qquad \forall \;\; j \neq LCI, \; v \neq LCI, \tag{9}$$

implying that the Norwegian Krone is the normalized currency choice.

Our model is a variant of the multinomial logit model, which we call the *conditional* compositional multinomial logit (CCML) model (Appendix A.2). Assuming currency choices to be independent of each other, gives rise to the multivariate Bernoulli likelihood function:

$$L(\boldsymbol{\theta}|\mathbf{x}_{nt}, \mathbf{Z}_t) = \prod_{n=1}^{N}\prod_{t=1}^{T}\prod_{j=1}^{J} \mathrm{P}_{jnt}^{s_{jnt}}, \tag{10}$$

where the probabilities are exponentiated by the actual observed currency shares and $\boldsymbol{\theta} \equiv [\boldsymbol{\alpha} \;\; \boldsymbol{\beta}_{PCI} \;\; \boldsymbol{\beta}_{VCI} \;\; \boldsymbol{\eta}_{PCI} \;\; \boldsymbol{\eta}_{VCI}]'$ is a row vector with parameters. Taking natural logarithms of (10), yields the multivariate Bernoulli log-likelihood function:

$$\ln L(\boldsymbol{\theta}|\mathbf{x}_{nt}, \mathbf{Z}_t) = \sum_{n=1}^{N}\sum_{t=1}^{T}\sum_{j=1}^{J} s_{jnt} \ln \mathrm{P}_{jnt}. \tag{11}$$

To arrive at the coefficient vector $\boldsymbol{\theta}$, equation (11) can be estimated by the maximum likelihood method. The estimated probabilities are then the predicted currency shares; that is,

[17] McFadden's (1974) derivation of the famous conditional logit model is identical to the steps that would have to be taken to go from (6) to (7).

$\hat{\text{P}}_{jnt} = \hat{s}_{jnt}$ where hats denote predicted values (Appendix A.3). In the benchmark specification, we explicitly control for unobserved heterogeneity across countries. To this end, we run a country-specific fixed effects model. Because T is larger than N, we do not have to deal with the well-known incidental parameter problem. As a robustness check, we also consider a pooled model. For this purpose, we replace $\mathbf{d}_n\boldsymbol{\eta}_v$ by a pooled constant a_v, which measures the trader's intrinsic preference for currency group v across countries. The set of explanatory variables consists of trade variables and monetary variables (Section 4.3). We use robust standard errors instead of clustered standard errors, reflecting the relatively small N (Appendix A.4).

4.2 The Dynamic Model

Even though the economic characteristics of a country or a currency (e.g., inflation and exchange rate volatility) can dramatically change in a short time period, trading partners typically stick to the same invoicing currency in settling their trade contracts. This phenomena of habit formation has been dubbed hysteresis in the international finance literature. To model hysteresis at the aggregate level, we extend model (5) to include the past invoicing share $s_{jn(t-q)}$ for lag $q = 1, ..., Q$. The dynamic model is given by:[18]

$$U_{jnt} = \mathbf{d}_n\boldsymbol{\eta}_v + \sum_{q=1}^{4} \gamma_q s_{jn(t-q)} + \mathbf{x}'_{nt}\boldsymbol{\beta}_v + \mathbf{z}'_{jt}\boldsymbol{\alpha} + \xi_{jnt}, \tag{12}$$

where γ_q is the coefficient for lag q and ξ_{jnt} is the error term. If $\gamma_q > 0$, then traders prefer the same currency in the current period as in the previous period, whereas for $\gamma_q < 0$, invoicing in another currency is preferred in the current period. The inclusion of the lagged dependent variable can cause inconsistency and bias in estimating a logistic regression model if the current error ξ_{jnt} is correlated with any lagged dependent variable $s_{jn(t-q)}$ (cf. Train, 2003). We find the correlation between ξ_{jnt} and $s_{jn(t-1)}$ to be around 0.63, which turns out significant in a formal test. Therefore, we only consider this specification in the robustness analysis.

[18]Because we only observe aggregate bilateral trade flows, the model can only serve as rough proxy for hysteresis in currency choice at the firm level.

4.3 Explanatory Variables

Because traders are likely to choose currencies according to their characteristics and not only the attributes of the currency's jurisdiction, we include both currency-specific and country-specific explanatory variables. The analysis includes dummies to capture the introduction of the euro and the transition period, a set of trade and trade-related variables, and monetary variables. A detailed overview of the data sources—and the way the variables are calculated—is provided in Table A.2, whereas Table A.3 presents descriptive statistics. The following sets out the explanatory variables used in the analysis.

4.3.1 Euro Dummies

To measure any unobserved effects on invoicing related to euro introduction, for example, trust in the stability of the common currency, we employ a dummy for countries participating in the eurozone EUR_{lt} for $l = \{j, n\}$, where l indicates whether the dummy is currency specific (denoted by j) or country specific (denoted by n). As a currency-specific variable, the euro dummy takes on a value of unity for the legacy currencies of the eurozone and the euro from January 1, 1999 onward and zero otherwise (where the legacy currencies are included up to December 31, 2001). As a country-specific variable, the dummy takes on a value of unity for all eurozone countries from January 1, 1999 onward. More euro invoicing because of a changes in fundamental variables (i.e., a larger world trade share of the eurozone or more stable inflation rates) should be captured sufficiently by the respective regressors. The parameter of the euro dummy variable is expected to have a positive sign, since countries will take advantage of the increased market power bestowed upon them by the euro and trade less in any other currency than their own.

During the transition period, the euro has been used in non-cash trade transactions alongside the legacy currencies—which continued to be used as legal tender—and thus did not yet assume its full weight. To measure the euro effect during the transition period, we use a dummy variable $EuroControl_{jt}$, which takes on a value of unity for the currency choice of one of the legacy currencies for the period January 1, 1999 to December 31, 2001 and zero otherwise. Note that the official date on which the national currencies of countries participating in the eurozone ceased to be legal tender varied across Member States, but lasted up to a maximum of two months after January, 2002. Based on the descriptive analysis in Section 3, we know that the euro slowly replaced the legacy currencies, yielding a negative coefficient of the $EuroControl_{jt}$ dummy. The marginal effect of this dummy will indicate the speed of the transition.

4.3.2 Trade Variables

A country's market share is a key determinant of currency choice (cf. Swoboda, 1968; Bacchetta and Van Wincoop, 2005; and Ligthart and Da Silva, 2007). Bacchetta and Van Wincoop (2005) argue that a larger world trade share increases a country's market power and thus its ability to impose its currency upon the trading partner. Country size itself plays no role. The effect of a country's world trade share $WorldTrade_{lt}$ is expected to be positive for PCI relative to invoicing in the Norwegian Krone (LCI). Because the need to use an international currency is reduced, the effect on VCI should be negative.

McKinnon (1979) argues that homogeneous products—which are typically traded on organized exchanges (e.g., oil)—are often priced and invoiced in leading vehicle currencies like the US dollar and the euro. Rauch (1999) distinguishes homogeneous products from reference-priced products, which are not traded on organized exchanges, but for which "reference prices" are available. Hence, firms cannot set their own price. In addition, referenced-priced goods are also likely to be fixed to a "reference currency" (usually a vehicle currency). Therefore, the share of reference-priced goods in Norwegian imports from country n (Ref_{nt}) is expected to have a positive effect on VCI and a negative effect on LCI and PCI. It is generally assumed that firms producing differentiated goods under monopolistic competition have power to set freely their prices and choose their currency of denomination. McKinnon (1979) argues that differentiated products are therefore more likely to be invoiced in the producer's currency. However, Krugman (1987) and Betts and Devereux (2000) point out that firms producing differentiated final goods have an incentive to "price to market." As a result, the share of differentiated products $Diff_{nt}$ is expected to have a negative effect on VCI and an ambiguous effect on LCI and PCI.

To control for the composition of trade across countries, the partner country's share in total Norwegian trade $NorwayTrade_{nt}$ is included. This variable captures the net effect on bilateral trade of distance (negative effect) and a country's GDP (positive effect). $NorwayTrade_{nt}$ is not likely to affect the preferences for either country's currency and, therefore, has an ambiguous effect on the trading partners' own currency shares (i.e., PCI and LCI). The effect on VCI, however, is expected to be negative. Indeed, if goods markets of two economies are becoming more integrated there will be less need for a third currency.

4.3.3 Monetary Variables

Magee and Rao (1980) hypothesize that trading firms are less likely to set their prices in currencies of countries that exhibit a high rate of inflation. A high inflation rate weakens a country's currency and erodes the real value of the firm's trade receipts. The expected rate of inflation of the partner country CPI_{lt} should have a negative effect on PCI by foreign exporters and on LCI by Norwegian exporters. Cornell (1980) and Devereux, Engel, and Storgaard (2004) argue that the expected volatility of inflation of the partner country $CPIVol_{lt}$ will similarly have a negative effect on use of the partner currency, because risk-averse exporters (importers) will want to minimize the variance of their receipts (payments).

According to Swoboda (1968), traders prefer a currency that has a thick foreign exchange market. Because of the smallness of a risk-averse trader relative to the market (atomicity), the risk of capital loss in a thick market is smaller than in a thin market. Krugman (1980) and Magee and Rao (1980) elaborate formally on the role of the lower transaction costs in deep, resilient markets. Therefore, the size of the foreign exchange market of the chosen currency $SizeFX_{lt}$ on the respective is expected to be positive.

Baron (1976) was the first to argue that exporters will prefer to invoice in the currency whose relative price has the least volatility with a view to avoid revenue risk. The expected (nominal) exchange rate volatility between the chosen currency and the Norwegian Krone $XVoltoNOK_{lt}$ is expected to decrease the share of the chosen currency, regardless whether this currency happens to be the producer's, local or a vehicle currency.[19] Similarly, the

[19]Note that the change in the nominal exchange rate is not included, since the shares have already been adjusted for exchange rate differences across years.

expected exchange rate volatility between the chosen currency and the producer's currency $XVoltoProd_{jt}$ is expected to decrease the share of the chosen currency, again regardless of the currency type.[20]

4.4 Structural Break Test

Because our analysis covers the time period of the introduction of the euro, we have included the euro dummy EUR_{jt} discussed above. Imposing the euro dummy to start in the year 1999 represents the belief that a major change in invoicing practices materialized then. However, it is not a priori clear whether and (if so) when such a structural break occurred. In particular, in view of the hysteresis in invoicing practices, the structural break is likely to take place later (if it occurred at all). Therefore, we perform a structural break test with unknown change point.

Formal tests for nonlinear models with an unknown change point have been devised and discussed by Andrews (1993). A model is said to exhibit parameter stability if the null hypothesis of no structural break:

$$H_0 : \boldsymbol{\theta}_t = \boldsymbol{\theta}_0 \qquad \text{for all} \qquad t \geq 1, \tag{13}$$

cannot be rejected. The alternative hypothesis of a structural change is given by:

$$H_1(\pi) : \boldsymbol{\theta}_t = \begin{cases} \boldsymbol{\theta}_1(\pi) & \text{for } \ t = 1, ..., T_\pi \\ \boldsymbol{\theta}_2(\pi) & \text{for } \ t = T_\pi + 1, ... \end{cases}, \tag{14}$$

where $\pi \in (0, 1)$ denotes the probability of a one-off structural change at date T_π and $\boldsymbol{\theta}_1(\pi)$ and $\boldsymbol{\theta}_2(\pi)$ denote the parameter before and after the structural change, respectively. Searching for the point of change can be approached in two ways. First, the point of change is known on a restricted interval $\Pi \subset (0, 1)$, where Π denotes the time period under consideration. In our case, the time span relates to the transition period from the introduction of the euro in non-cash form in 1999 to the introduction of euro coins and notes in 2002. We thus specify $\Pi = [13/44, 25/44]$, where 13 is the first quarter of 1999, 25 is the last quarter of 2001, and 44 denotes the total number of quarters. Second, if one assumes the absence of information

[20]By construction $XVoltoNOK_{lt}$ and $XVoltoProd_{jt}$ are zero for LCI and PCI, respectively.

regarding the time of change, all change points are of interest on the $(0,1)$ interval. However, since the proposed likelihood ratio (LR) test statistic diverges to infinity at the extreme points of 0 and 1, Andrews (1993) suggests to only use the restricted interval $\Pi = [0.15, 0.85]$. In our model, this would imply the interval $\Pi = [7/44, 37/44]$. The $\sup_{\pi \in \Pi} LR_T(\pi)$ is calculated as follows:

$$\max\{-2\,[LL(\boldsymbol{\theta}_U) - LL(\boldsymbol{\theta}_{R,\,\forall\, t \leq T_\pi}) - LL(\boldsymbol{\theta}_{R,\,\forall\, t > T_\pi})]\} \quad \forall\ T_\pi \in \Pi, \tag{15}$$

where LL denotes the log-likelihood and R and U denote the restricted model and unrestricted model, respectively. If the $\sup_{\pi \in \Pi} LR_T(\pi)$ is larger than the critical value[21] then the null hypothesis of no structural break can be rejected.

5 Results

This section presents the results. We start off with the benchmark specification, including the variables discussed above, and subsequently present a robustness analysis.

5.1 Benchmark Specification

The first column of Table 3 sets out the fixed effects benchmark model. [22] Within the set of currency-specific variables only the euro dummies EUR_{jt} and $EuroControl_{jt}$ are significant and have the expected sign. After the introduction of the euro, eurozone currencies are chosen more frequently and the legacy currencies of the eurozone are chosen less often in the transition period. The size of the foreign exchange market $SizeFX_{jt}$ is not significant. In addition, both exchange rate volatility variables (i.e., $XVoltoNOK_{jt}$ and $XVoltoProd_{jt}$) are not significant, which might be explained by the nature of the data; we only observe aggregate currency shares and thus cannot track currency use in single transactions. In this context,

[21] Asymptotic critical values for up to 20 parameters are provided by Andrews (1993). However, since our benchmark specification is a fixed effects model with 73 parameters, we calculate the asymptotic critical values using Andrews's GAUSS code.

[22] We formally tested whether we should employ a fixed effects or a pooled specification. Using the likelihood ratio test under the null hypothesis that the pooled model and the fixed effects model are statistically the same, yields: $-2[LL(a_v) - LL(\mathbf{d}_n\boldsymbol{\eta}_v)] = 241.97 > 39.8 = \chi^2(56)$, where I and II denote Specification I (the benchmark) and Specification II, respectively. Because there are 29 countries in the analysis, we have $2 \times 28 = 56$ restrictions. The test statistic indicates that the hypothesis of poolability across countries can be rejected, that is, the fixed effects model is more suitable.

large transactions of large firms may outweigh many small transactions of small firms,[23] which often do not have access to sophisticated financial products to hedge exchange rate risk.[24]

Within the set of country-specific variables, the variables CPI_{nt}, $CPIVol_{nt}$, and $Diff_{nt}$ are significant and also have the expected sign. The exporter's currency is chosen less if its economy's inflation volatility is higher and a vehicle currency is chosen less if the exporter's inflation rate is higher.[25] The share of vehicle currencies also decreases if the export package of Norway's trading partner consists of more differentiated products, which is in line with the stylized fact identified by McKinnon (1979). Finally, the pseudo R^2 of the benchmark model is almost 0.4, which is rather high within the class of logit models.

In nonlinear models, the slope coefficients do not have the same interpretation as in linear models. Using average marginal effects, we can also interpret the magnitudes of the effects of the covariates on invoicing shares. The left panel of Table 4 presents the marginal effects for country-specific variables in the benchmark specification. Note that the signs and significance of the estimated coefficients of the country-specific variables can differ from those in the marginal effects analysis because the marginal effect of a covariate and its standard error are calculated using the estimated coefficients and their respective standard errors of the other currency groups as well (Appendix A.5). An increase of one standard deviation in the inflation volatility of the exporter's economy reduces PCI by 10.7 percent and increases the use of the local currency and vehicle currencies by 6.8 and 3.9 percent, respectively.[26] The magnitudes of the inflation rate across currency groups are small and statistically insignificant for all three currency groups. A 10 percent increase in the share of differentiated products decreases the use of vehicle currencies by 5 percent.

The right panel of Table 4 presents the marginal effects of significant currency-specific variables. Figures on the diagonal of each matrix represent the own effect and figures off

[23] The difficulty of differentiating between large transactions and small transactions is an example of the ecological inference problem as defined in equation (5).

[24] Borsum and Odegaard (2005) survey Norwegian firms about their currency hedging practices and find that small firms use more primitive hedging methods such as invoicing in the home currency, whereas large firms use forward contracts and currency options.

[25] Ligthart and Da Silva (2007) also included this variable in their analysis, but it was not significant in the benchmark specification.

[26] Those magnitudes are very large, since we have already controlled for unobserved heterogeneity. Table 6 presents the magnitudes for the pooled model. See Section 5.2.

the diagonal denote cross effects (i.e., with respect to the other two currency groups). If the currency is the euro, then its share increases by 1.4 percent when used as a producer currency, whereas if it is chosen as a vehicle currency its share increases by 1.6 percent.[27] Interestingly, if the Norwegian Krone were part of the eurozone, its share would increase by almost 2 percent (see the first entry on the diagonal for the EUR_{jt} dummy). The coefficient of $EuroControl_{jt}$ indicates the speed of transition from the national legacy currency to the euro or any other currency. If the exporter's currency is a currency of the eurozone, then it reduces its invoicing share of the national legacy currency in any quarter between 1999 and 2001 by 1.1 percent and as a vehicle currency by 1.3 percent.

5.2 Robustness Analysis

To check for robustness, we drop the fixed effects and analyze a pooled model (Specification II). Compared to the benchmark, the set of significant variables expands. Within the set of currency-specific variables, $SizeFX_{jt}$ becomes significant with the correct sign. $NorwayTrade_{nt}$, a country-specific variable, now turns significant and has the correct sign too. The coefficient of $NorwayTrade_{nt}$ for vehicle currencies indicates that there is less need for a vehicle currency as trade between two economies increases. $Diff_{nt}$ is significant and has a negative sign, pointing toward LCI by foreign exporters. To save on space, we use a (+) or (−) in Table 3 to indicate the sign of significant marginal effects for country-specific variables. We can see that the signs of the significant parameters are in line with those of the marginal effects. Pooling the model reduces the explanatory power somewhat.

We investigate habit formation by running a dynamic model (Specification III), which extends the fixed effects benchmark specification by including the invoicing shares of the currency groups during the last four quarters. The invoicing share of the previous quarter is significant and positive, supporting the presence of "habit formation" in invoicing in the short run. In the medium to long run, there is no indication of hysteresis. The set of significant variables—and the sign of the marginal effects—is roughly in line with the benchmark outcome. Interestingly, $XVoltoProd_{jt}$ turns out to be significant with the expected sign, implying

[27] The marginal effects are usually small in logit models, because the estimated probabilities are bounded between zero and one.

that the foreign exporter chooses a currency that is less volatile relative to its home currency.

One could argue that producers from a country in which the currency has a deep and resilient foreign exchange market prefer their own currency. Consequently, they choose less often a vehicle currency. We could also test whether traders choose a currency that has the least inflation volatility. Specifying inflation volatility as a currency-specific variable models the inflation volatility of the producer's currency relative to any other country's inflation volatility, including Norway's.[28] To test these two propositions, the size of foreign exchange market enters the equation as a country-specific variable and inflation volatility becomes a currency-specific variable (Specification IV). We see that both $SizeFX_{nt}$ and $CPIVol_{jt}$ are significant. If the producer's currency has a large foreign exchange market, its currency is invoiced more often and the share of vehicle currencies decreases. A currency is chosen less if the inflation volatility of its economy increases.

Because Specification IV yields various new significant variables, we also report average marginal effects (Table 6). Inflation volatility as currency-specific variable $CPIVol_{jt}$ has rather small magnitudes across currency groups. An increase of Norway's inflation volatility by one standard deviation reduces the invoicing share of the Norwegian Krone by less than one percent. The same increase of the exporter's inflation volatility reduces his own currency's invoicing share by less than half of a percent. A 10 percent increase in the size of the partner currency's foreign exchange market $SizeFX_{nt}$ leads to an increase of 6 percent of the producer currency's share, a fall of almost 2 percent of the local currency share, and a decrease of around 4 percent of vehicle currencies. A similar 10 percent increase of differentiated products $Diff_{nt}$ leads to a 5 percent increase (decrease) of local currency (vehicle) currencies, respectively. Rather large is the magnitude of the inflation effect; an increase of 10 percent of the producer's country inflation rate causes an almost 14 percent loss of the producer's currency share and increases the local currency share by almost 11 percent.

Table 5 presents additional robustness checks. Specification V shows the benchmark model without the euro dummy EUR_{jt}. $XVoltoProd_{jt}$ turns significant with the correct negative sign while it was insignificant in the benchmark. It could be argued that choosing the euro reduces

[28] Devereux, Engel, and Storgaard (2004) argue that a country's inflation volatility only matters with respect to its trading partner's inflation volatility.

the effect of exchange rate volatility with respect to the exporter's currency, an effect that is captured when the euro dummy is included. Specification VI modifies the benchmark model by replacing the share of differentiated products Diff_{nt} with the share of reference-priced products Ref_{nt}. Increasing the share of reference-priced products decreases the use of the exporter's currency. Specification VII takes CPI_{jt}, CPIVol_{jt}, and $\mathit{WorldTrade}_{jt}$ as currency-specific variables. CPI_{jt} is significant, but has an incorrect (positive) sign. $\mathit{WorldTrade}_{jt}$ is insignificant, in line with its insignificance as a currency-specific variable.

Table 7 presents specifications with country-specific variables only.[29] Specification VIII shows a pooled model, which resembles the approach taken by the rest of the invoicing literature. All trade variables—including the control variable $\mathit{NorwayTrade}_{nt}$—are significant, in line with the findings of other authors (cf. Ligthart and Da Silva, 2007). Inflation and inflation volatility both are significantly negative in case of PCI, whereas the size of the foreign exchange market has a negatively significant effect on VCI. The marginal effects of all variables—except that of Diff_{nt} in VCI—are significant and have the correct sign. Specification IX implements country fixed effects and finds a smaller set of significant variables than in the previous specification. However, the euro dummy is significant and has the correct sign for both PCI and VCI.

5.3 Structural Break Test

Figure 3 presents the LR test statistic of a structural change for various model specifications. Panel (a) shows that the test statistic reaches its maximum in 2002, but does not indicate a structural change at the 10 percent level of significance. Even though the descriptive analysis of Section 3 revealed a major change in invoicing practices, the model and its significant covariates—i.e., *EUR*, *EuroControl*, *CPIVol*, *CPI*, and *Diff*—account well enough for these changes. Panel (b) is using specification V without the euro dummy. The statistic touches the 10 percent level of significance in 2001, indicating that the euro dummy controls for the break to a certain degree. Panel (c) is based on Specification II, which is the pooled version of the benchmark model. The test statistic indicates a break in 2001 at the 5 percent level

[29] We can no longer distinguish between the *EUR* and *EuroControl* dummies, because the latter is a currency-specific variable.

and is above the 10 percent level for around five quarters from 2001Q1 onward.

5.4 The Effect of the Euro on Individual Countries and the Eurozone

To get insight into the euro effect on currency shares of individual countries, we calculate marginal effects at a representative value of the covariate of interest. We select three eurozone countries, that is, Germany, Greece, and Italy. Germany is chosen because it is a country with a low inflation volatility, whereas Greece and Italy feature high inflation volatilities. We also compute what would have happened if selected non-eurozone countries (e.g., Canada, Japan, and the United States) had adopted the euro. We choose Canada to measure the effect the euro has on a country that trades predominantly with the United States. Japan is included because it is marked as an outlier in the invoicing literature, owing to its relatively low share of PCI.[30] Finally, the United States is interesting due to the US dollar's vehicle currency role, which yields a high share of PCI in Norwegian imports (Table A.1). To check for the robustness of the euro effect across time, we also compute the counterfactual of euro introduction in the last quarter of 1998.

Table 8 reports the marginal effects of the countries in question in the last quarter of 1998 and 2006. The euro dummy captures the direct (unobserved) effect of euro introduction; it is significant in all three eurozone countries, but there is not much of a difference between 1996 and 2006. Above and beyond the effects of the covariates, Greece and Italy—and the Mediterranean countries in the eurozone more generally (not reported)—benefited the most in 2006 from having adopted the euro. In the case of Canada, the euro dummy is not significant. If Japan were part of the eurozone, it would have increased PCI by nearly 2 percent in 1998 and almost 3 percent in 2006, which is smaller than for eurozone countries. If the United States were to adopt the euro, its currency share in 2006 would have gone up as much as that of Germany. These results indicate that the introduction of the euro also would have had an impact outside the European continent.

Part of the euro effect may have manifested itself indirectly through its beneficial effect

[30] Japan tends to invoice its exports in the local currency to a much greater extent than would be expected given its economic size. This invoicing pattern can be explained by Japan's small market share in world trade. In addition, more than half of Japan's exports to OECD countries go to the United States and this biases the invoicing decision toward the US dollar.

on price and inflation stability. When Greece joined the euro, it boosted its PCI immediately via the unobserved euro effect, but also enjoyed an increase in its PCI share via a reduction in inflation volatility. In 1998, Greece has (in absolute terms) a smaller marginal effect of inflation volatility than Germany and Italy, even though Greece's inflation volatility is as high as that of Italy. A one standard deviation increase of inflation volatility decreases PCI of Germany, Greece, and Italy by 17 percent, 14 percent, and 18 percent, respectively. In 2006, when all three countries were part of the eurozone, Germany's marginal effect is -14 percent and that of Greece is -17 percent.[31] $CPIVol_{nt}$ is not significant with respect to the invoicing of the Canadian dollar, but it is significant with respect to VCI and LCI (the latter is not reported in the table), where the former has a magnitude of 0.1.

We investigate to what extent the increase in the PCI share of eurozone countries can be attributed to a change in the fundamentals. Inflation volatility in the eurozone—measured as the standard deviation of inflation—dropped from 0.5 in 1998Q4 to 0.25 in 2006Q4. Using inflation volatility data for 1998Q4, we derive the predicted PCI share of eurozone countries in 2006Q4 if the volatilities were still as high as in the late 1990s. We find that the predicted PCI share drops from 0.46 (when 2006Q4 data are used for all controls) to 0.33 (when 1998Q4 inflation volatility data are used while all other controls are set at 2006Q4 values), suggesting that the drop in inflation volatility played a large role in the rise in the PCI share after euro introduction.

6 Conclusions

The paper analyzes the effect of euro introduction on invoicing currency choice. We use a conditional compositional multinomial logit approach, in which trader's invoicing motives can be directly linked to the attributes of the currencies rather than to countries' characteristics only. To this end, we use quarterly panel data on invoicing of Norwegian imports from OECD countries covering the period 1996–2006. We test the stability of our model using Andrews's

[31]Greece's PCI share is low in 1998 (on the order of 3 percent) and rather high in 2006 (roughly 65 percent). In view of these PCI shares, an increase of Greece's inflation volatility could possibly not reduce its invoicing in producer currencies much more in 1998, but there is more room in 2006. Given that Greece has a greater PCI share in more recent years might make it more prone to inflation volatility.

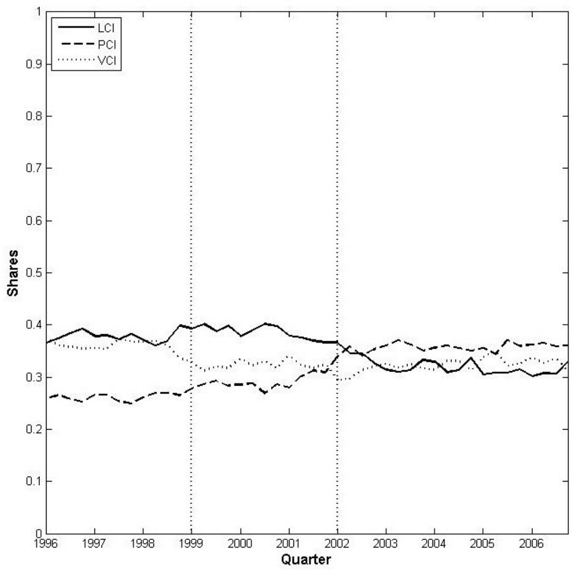
structural change test with an unknown breakpoint.

In the descriptive analysis, we show that eurozone exporters have increased their home currency share at the expense of both local and vehicle currencies. The euro has replaced the US dollar as the dominant currency in the group of vehicle currencies. In the econometric analysis—after having controlled for unobserved country heterogeneity and changes in the fundamentals—we find that the euro has had a significant positive effect on the euro share (as well as the shares of producer and vehicle currencies). In addition, inflation volatility is shown to be significant and negatively affects a partner country's currency share. Other significant variables (taking the benchmark model) are the inflation rate and the degree of product differentiation. In alternative specifications, we find the size of the foreign exchange market and the invoicing share in the previous quarter to have a significantly positive effect on the respective currency shares, whereas the share of eurozone legacy currencies is significantly negative. We derive average marginal effects and find that the drop in inflation volatility has boosted producer currency invoicing by eurozone countries the most, followed by the unobserved effect of euro introduction. Conditional on the fundamentals, the producer currency shares of Mediterranean countries in the eurozone enjoyed the highest increase from euro adoption. Last but not least, the structural break test supports the stability of our model parameters. Although the test statistic shows a peak around the time of euro introduction, it does not exceed the 10 percent level of significance.

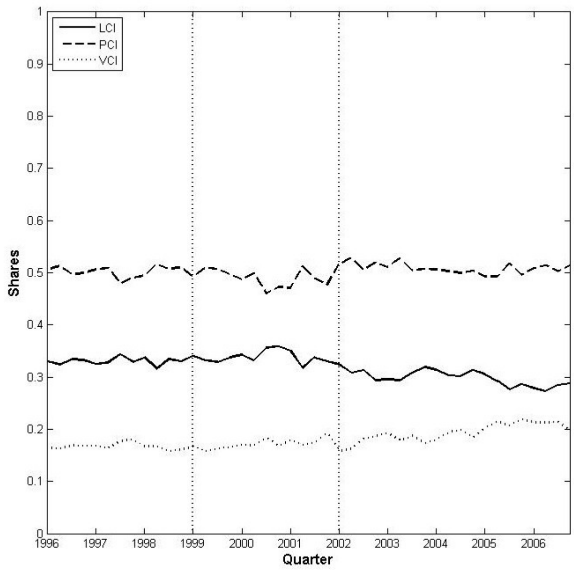
Future research could focus on invoicing transactions at the firm level, potentially via a survey of eurozone firms. Such a micro-based approach has the advantage that information on firm size and transaction volumes can be used in the analysis. Second, to check the robustness of the findings, invoicing data for other countries than Norway could be analyzed. Finally, the currency of invoicing is largely settled through negotiations between the exporting and importing firm. A dynamic cooperative bargaining model would have to be developed to capture these interactions.

Figure 1: Invoicing Shares in Norwegian Imports from OECD Countries

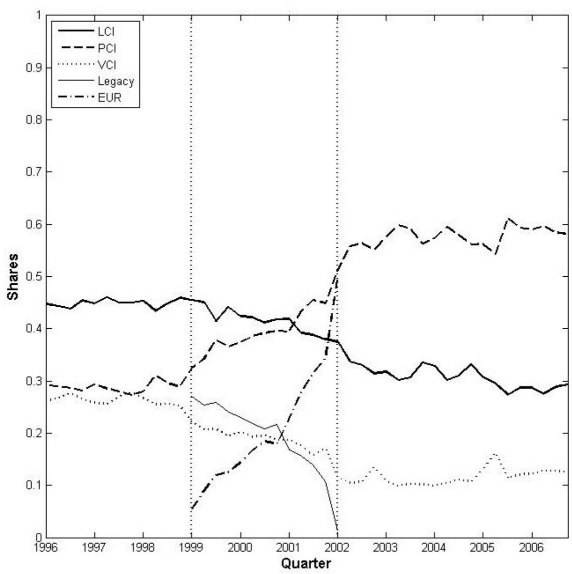
(a) 29 OECD countries (equally weighted)



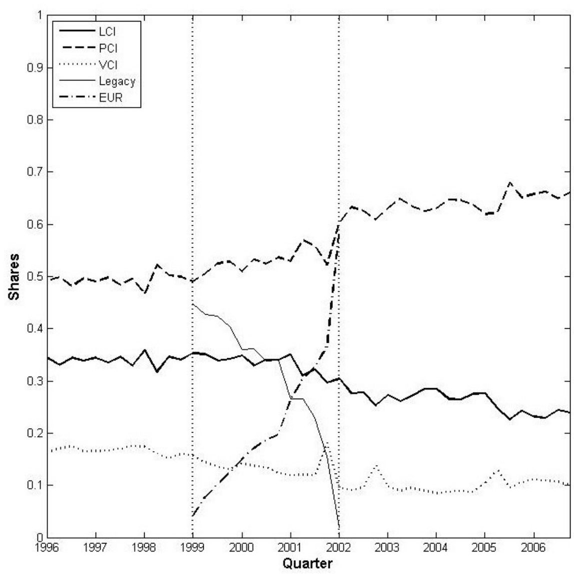
(b) 29 OECD countries (trade weighted)



(c) Eurozone countries (equally weighted)



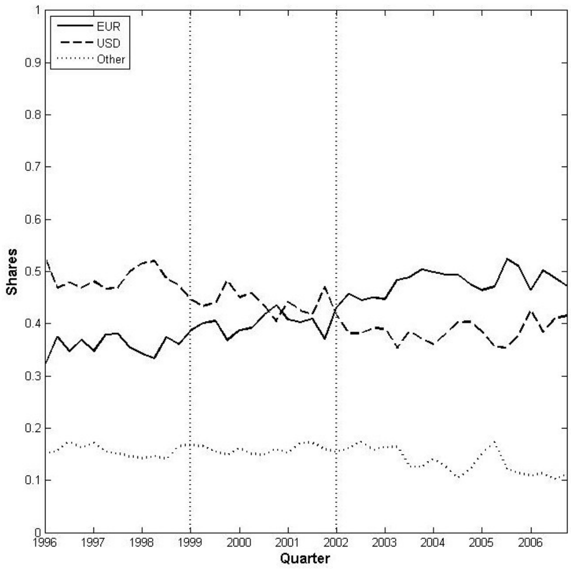
(d) Eurozone countries (trade weighted)



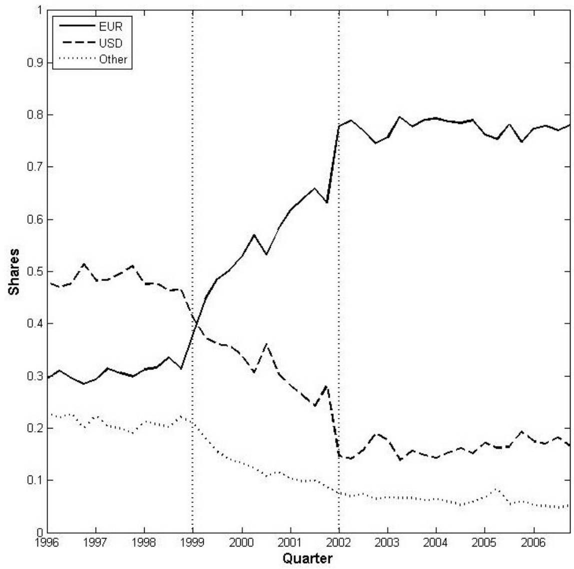
Notes: The data pertain to all OECD countries excluding Norway. The first vertical line indicates the introduction of the euro in non-cash form, whereas the second vertical line represents the introduction of the euro in cash transactions. The thick solid line represents the share of local currency invoicing (LCI), the dashed line denotes the share of producer currency invoicing (PCI), the dotted line depicts the share of vehicle currency invoicing (VCI), the dashed dotted line denotes the euro share, and the thin solid line represents the euro legacy currencies.

Figure 2: Vehicle Currency Use in Norwegian Imports from OECD Countries

(a) 29 OECD countries (equally weighted)



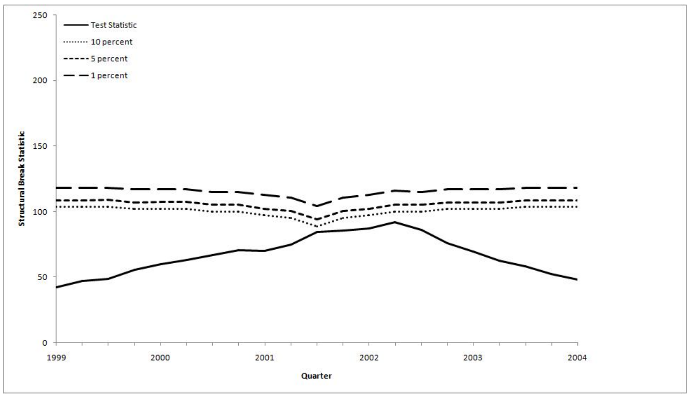
(b) 29 OECD countries (trade weighted)



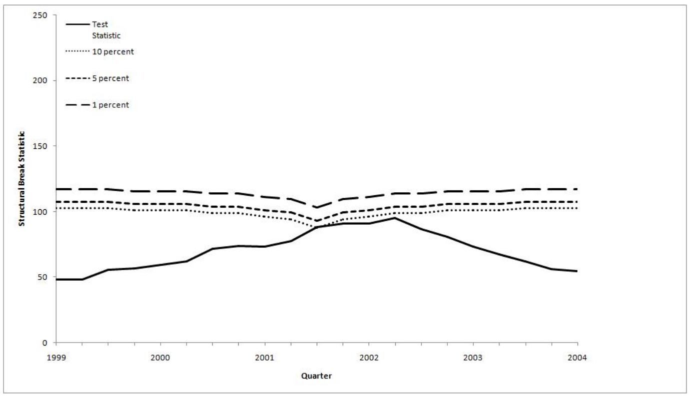
Notes: The data pertain to all OECD countries excluding Norway. The first vertical line indicates the introduction of the euro in non-cash form, whereas the second vertical line represents the introduction of the euro in cash transactions. The solid line represents the US dollar (USD) share, the dashed line depicts the euro (EUR) share, and the dotted line denotes the share of other currencies. Note that before January 1, 2002, the legacy currencies that were used as a vehicle currency are also counted toward the euro share.

Figure 3: Likelihood Ratio Test Statistic of a Structural Change, 1999–2004

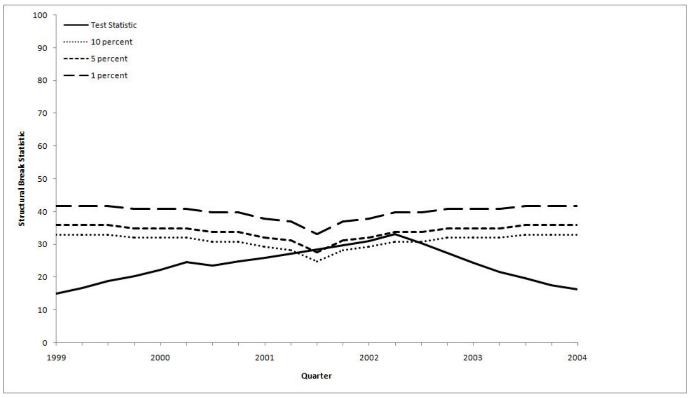
Panel (a): Including Euro Dummy (Fixed Effects Model)



Panel (b): Excluding Euro Dummy (Fixed Effects Model)



Panel (c): Including Euro Dummy (Pooled Model)



Notes: Panel (a) is based on Specification I of Table 3, whereas Panels (b) and (c) are based on Specification V of Table 5 and Specification II of Table 3, respectively. The solid line represents the test statistic, the big dashed line is the 1 percent level of significance, the small dashed line denotes the 5 percent level of significance, and the dotted line is the 10 percent level of significance.

Table 1: Vehicle Currency Shares, 1996 and 2006

Year	Currencies	Share of All Currencies	Share of All Vehicle Currencies
1996	Total	37.4666	100.0000
	US dollar	19.7697	52.7662
	Eurozone	12.0287	32.1052
	German mark	10.1230	27.0186
	Dutch guilder	0.6693	1.7864
	Belgian franc	0.4894	1.3062
	ECU	0.3444	0.9192
	Austrian schilling	0.1645	0.4392
	French franc	0.1381	0.3685
	Finnish mark	0.0529	0.1411
	Lira	0.0258	0.0689
	Irish pound	0.0113	0.0302
	Spanish peseta	0.0072	0.0193
	Portuguese escudo	0.0028	0.0075
	Non-eurozone	5.6682	15.1286
	Swedish krona	3.4730	9.2697
	Danish krone	1.1570	3.0881
	Pound sterling	0.7503	2.0026
	Swiss franc	0.2421	0.6463
	Japanese yen	0.0389	0.1037
	Canadian dollar	0.0060	0.0160
	Australian dollar	0.0007	0.0018
	Iceland krona	0.0001	0.0003
2006	Total	30.9928	100.0000
	Euro	14.6061	47.1274
	US dollar	12.8751	41.5424
	Swedish krona	2.1265	6.8612
	Danish krone	0.9188	2.9644
	Pound sterling	0.3650	1.1777
	Swiss franc	0.0533	0.1721
	Japanese yen	0.0237	0.0763
	Canadian dollar	0.0175	0.0566
	Czech koruna	0.0027	0.0087
	Zloty	0.0025	0.0080
	Australian dollar	0.0015	0.0047
	New Zealand dollar	0.0001	0.0003
	Iceland krona	0.0000	0.0001

Notes: The first column with data presents the average share with respect to all currencies (including LCI and PCI), whereas the second column shows the average share with respect to all vehicle currencies.

Table 2: Vehicle Currencies Used in Norway's Imports from OECD Countries, 1996–2006

Time Period	Eurozone		Non-Eurozone		United States		Total	
	Max	Mean	Max	Mean	Max	Mean	Max	Mean
1996–1998	23.0	16.1	23.0	15.0	22.0	20.7	23.0	15.6
	(12.0)	(9.1)	(13.0)	(8.4)	(12.0)	(11.3)	(13.0)	(8.8)
1999–2001	22.0	15.8	22.0	15.8	21.0	19.7	22.0	15.9
	(12.0)	(8.5)	(12.0)	(7.8)	(12.0)	(10.0)	(12.0)	(8.2)
2002–2006	17.0	8.7	18.0	9.1	18.0	13.0	18.0	9.0

Notes: The numbers in between brackets are the number of legacy currencies of the countries participating in the eurozone. No legacy currencies could be used after January 1, 2002. The group of non-eurozone countries excludes the United States because the US dollar is a key vehicle currency and would distort the pattern.

Table 3: Results for Specifications I–IV

	(I)		(II)		(III)		(IV)	
Currency Specific								
EUR	0.1748***		0.3235***		0.1186***		0.0942***	
	(0.0223)		(0.0221)		(0.0299)		(0.0213)	
EuroControl	-0.1403***		-0.1947***		-0.1855***		-0.1858***	
	(0.0286)		(0.0286)		(0.0368)		(0.0244)	
SizeFX	0.0009		0.0111***		0.0010			
	(0.0011)		(0.0007)		(0.0008)			
XVoltoNOK	0.5087		-0.7727*		0.3965		0.6307	
	(0.3679)		(0.4555)		(0.3905)		(0.4070)	
XVoltoProd	-0.6490		0.1493		-0.8816***		-0.1690	
	(0.4065)		(0.4467)		(0.4088)		(0.4189)	
CPIVol							-0.0292***	
							(0.0059)	
PastShare t-1					0.5879***			
					(0.1712)			
PastShare t-2					0.0778			
					(0.2212)			
PastShare t-3					-0.2432			
					(0.2190)			
PastShare t-4					-0.3713**			
					(0.1881)			
Country Specific: PCI								
CPI	-0.0492		-0.1960***	(−)	-0.0223		-0.0988***	(−)
	(0.0321)		(0.0245)		(0.0278)		(0.0292)	
CPIVol	-0.7142***	(−)	-1.1458***	(−)	-0.7381***	(−)		
	(0.1342)		(0.1631)		(0.1371)			
SizeFX							0.0362***	(+)
							(0.0046)	
WorldTrade	0.0037		0.0288		0.0039		0.0031	
	(0.1819)		(0.0473)		(0.2120)		(0.1967)	
NorwayTrade	0.0131		0.1050***	(+)	0.0142		0.0110	
	(0.0541)		(0.0090)		(0.0546)		(0.0539)	
Diff	-0.0119		-0.0131***	(−)	-0.0139*		-0.0159**	
	(0.0081)		(0.0029)		(0.0081)		(0.0079)	
Constant			1.1519***					
			(0.2243)					
Country Specific: VCI								
CPI	-0.0136***		0.0037**	(+)	-0.0132***		-0.0154***	
	(0.0036)		(0.0016)		(0.0038)		(0.0037)	
CPIVol	-0.0083	(−)	0.0272**	(+)	-0.0185	(−)		
	(0.0176)		(0.0127)		(0.0202)			
SizeFX							-0.0131***	(−)
							(0.0037)	
WorldTrade	-0.0010		0.0003		-0.0009		-0.0008	
	(0.2025)		(0.0001)		(0.2293)		(0.2035)	
NorwayTrade	-0.0093		-0.0081***	(−)	-0.0102		-0.0080	
	(0.0652)		(0.0336)		(0.0672)		(0.0668)	
Diff	-0.0351***	(−)	-0.0811**		-0.0338***	(−)	-0.0347***	(−)
	(0.0057)		(0.0102)		(0.0066)		(0.0058)	
Constant			-3.1138***	(−)				
			(0.1278)					
Observations	1,276		1,276		1,160		1,276	
Log-likelihood	-2,493.17		-2,614.15		-2,252.63		-2,491.57	
Pseudo R^2	0.39		0.36		0.39		0.39	

Notes: The dependent variable is the probability of currency j being chosen. Traders can choose from three currencies (PCI, LCI, and VCI), where we have normalized the coefficients of the country-specific variables for LCI. The top panel reports estimated coefficients of currency-specific variables, whereas the bottom panels report country-specific variables. ***, **, * denote significance at the 1, 5 or 10 percent level, respectively. Robust standard errors are reported in parentheses below the parameter estimates. All significant marginal effects are given by a (+) or (−), indicating the direction of the effect. The identified marginal effects are all significant at the 1 percent level, except the ones that have a †, which are significant at the 5 percent level.

Table 4: Average Marginal Effects for the Benchmark Specification

Country Specific		Currency Specific			
LCI		*EUR*			
			LCI	**PCI**	**VCI**
CPI	0.0061*	**LCI**	0.0196***	-0.0088***	-0.0108**
	(0.0032)		(0.0044)	(0.0020)	(0.0055)
CPIVol	0.0678***	**PCI**		0.0141***	-0.0052***
	(0.0127)			(0.0032)	(0.0017)
Diff	0.0051**	**VCI**			0.0161***
	(0.0024)				(0.0040)
PCI		*EuroControl*†			
			LCI	**PCI**	**VCI**
CPI	-0.0066	**LCI**	-0.0143***	0.0062***	0.0080
	(0.0048)		(0.0029)	(0.0013)	(0.0045)
CPIVol	-0.1068***	**PCI**		-0.0108***	0.0045***
	(0.0200)			(0.0022)	(0.0015)
Diff	0.0002	**VCI**			-0.0126***
	(0.0012)				(0.0026)
VCI					
CPI	0.0005				
	(0.0020)				
CPIVol	0.0388***				
	(0.0124)				
Diff	-0.0053***				
	(0.0014)				

Notes: The left-hand side gives the marginal effects for the country-specific variables, whereas the right- hand side presents the marginal effects for the currency-specific variables. The latter panel presents on the diagonal the elasticities with respect to the own currency group and reports off-diagonal the elasticities with respect to the other currency group (i.e., PCI, LCI, and VCI). ***, **, * denote significance at the 1, 5 or 10 percent level, respectively. Robust standard errors are reported in parentheses below the parameter estimates. A † indicates that we have averaged the *EuroControl* dummy across all n countries and $t = 1999Q1, ..., 2001Q4$ (i.e., the transition period).

Table 5: Results for Specifications V–VII

	(V)		(VI)		(VII)	
Currency Specific						
EUR			0.1415***		0.1885***	
			(0.0223)		(0.0307)	
EuroControl	-0.0890***		-0.1457***		-0.1909***	
	(0.0269)		(0.0288)		(0.0328)	
SizeFX	0.0005		0.0010		0.0002	
	(0.0011)		(0.0011)		(0.0016)	
CPI					0.0041***	
					(0.0010)	
CPIVol					-0.0476***	
					(0.0067)	
XVoltoNOK	0.1157		0.3844		-0.2214	
	(0.3825)		(0.3563)		(0.4392)	
XVoltoProd	-0.9164***		-0.0997		0.3296	
	(0.4251)		(0.3954)		(0.4208)	
WorldTrade					0.0034	
					(0.0129)	
Country Specific: PCI						
CPI	-0.0569		-0.0609*	(−)		
	(0.0337)		(0.0349)			
CPIVol	-0.7088	(−)	-0.7089***	(−)		
	(0.1359)		(0.1371)			
WorldTrade	0.0035		0.0031			
	(0.1835)		(0.1848)			
NorwayTrade	0.0123		0.0109		0.0079	
	(0.0552)		(0.0527)		(0.0558)	
Diff	-0.0101				-0.0100	
	(0.0086)				(0.0078)	
Ref			-0.0210**	(−)		
			(0.0090)			
Country Specific: VCI						
CPI	-0.0152***		-0.0009			
	(0.0037)		(0.0031)			
CPIVol	-0.0039	(+)	-0.0174	(+)		
	(0.0177)		(0.0182)			
WorldTrade	-0.0010		-0.0067			
	(0.2082)		(0.1999)			
NorwayTrade	-0.0089		-0.0327		-0.0063	
	(0.0671)		(0.0646)		(0.0654)	
Diff	-0.0349***	(−)			-0.0407***	(−)
	(0.0061)				(0.0064)	
Ref			-0.0090			
			(0.0048)			
Observations	1,276		1,276		1,276	
Log-likelihood	-2495.3		-2490.04		-2506.36	
Pseudo R^2	0.39		0.39		0.39	

Notes: The dependent variable is the probability of currency j being chosen. Traders can choose from three currencies (PCI, LCI, and VCI), where we have normalized the coefficients of the country-specific variables for LCI. The top panel reports estimated coefficients of currency-specific variables, whereas the bottom panels report country-specific variables. ***, **, * denote significance at the 1, 5 or 10 percent level, respectively. Robust standard errors are reported in parentheses below the parameter estimates. All significant marginal effects are given by a (+) or (−), indicating the direction of the effect. The identified marginal effects are all significant at the 1 percent level, except the ones that have a †, which are significant at the 5 percent level.

Table 6: Average Marginal Effects for the Robust Specification IV

Country Specific		Currency Specific			
LCI		*EUR*			
			LCI	**PCI**	**VCI**
CPI	0.0109***	**LCI**	0.0196***	-0.0088***	-0.0108**
	(0.0028)		(0.0044)	(0.0020)	(0.0055)
SizeFX	-0.0018**	**PCI**		0.0141***	-0.0052***
	(0.0009)			(0.0032)	(0.0017)
Diff	0.0054***	**VCI**			0.0161***
	(0.0020)				(0.0040)
PCI		*EuroControl*†			
			LCI	**PCI**	**VCI**
CPI	-0.0137***	**LCI**	-0.0187***	0.0085***	0.0101**
	(0.0043)		(0.0024)	(0.0011)	(0.0037)
SizeFX	0.0060***	**PCI**		-0.0144***	0.0058***
	(0.0007)			(0.0018)	(0.0014)
Diff	-0.0004	**VCI**			-0.0160***
	(0.0011)				(0.0029)
VCI		*CPIVol*			
			LCI	**PCI**	**VCI**
CPI	0.0028	**LCI**	-0.0063***	0.0028***	0.0034**
	(0.0020)		(0.0012)	(0.0006)	(0.0016)
SizeFX	-0.0042***	**PCI**		-0.0045***	0.0017***
	(0.0009)			(0.0009)	(0.0005)
Diff	-0.0050***	**VCI**			-0.0051***
	(0.0013)				(0.0012)

Notes: The left-hand side gives the marginal effects for the country-specific variables, whereas the right- hand side presents the marginal effects for the currency-specific variables. The latter panel presents on the diagonal the elasticities with respect to the own currency group and reports off-diagonal the elasticities with respect to the other currency group (i.e., PCI, LCI, and VCI). ***, **, * denote significance at the 1, 5 or 10 percent level, respectively. Robust standard errors are reported in parentheses below the parameter estimates. A † indicates that we have averaged the *EuroControl* dummy across all n countries and $t = 1999Q1, ..., 2001Q4$ (i.e., the transition period).

Table 7: Results for Specifications VIII–IX

	(VIII)		(IX)	
Country Specific: PCI				
CPI	-0.1971***	(−)	-0.0372	
	(0.0248)		(0.0268)	
CPIVol	-0.9123***	(−)	-0.3879***	(−)
	(0.1532)		(0.1010)	
SizeFX	0.0005	(+)†	0.0251**	(+)†
	(0.0056)		(0.0115)	
XVoltoNOK	-4.9860**	(−)	1.8927	
	(2.3293)		(1.3520)	
WorldTrade	0.6421***	(+)	0.0321	
	(0.0689)		(0.1332)	
NorwayTrade	0.0495***	(+)	0.0541	
	(0.0080)		(0.0428)	
Diff	-0.0191***	(−)	0.0006	
	(0.0027)		(0.0052)	
EUR	0.7891***	(+)	0.5197**	(+)
	(0.1050)		(0.2001)	
Constant	1.2650***			
	(0.2169)			
Country Specific: VCI				
CPI	-0.0004	(+)	0.0044*	(+)†
	(0.0024)		(0.0023)	
CPIVol	0.0051	(+)	-0.0051	(+)
	(0.0165)		(0.0140)	
SizeFX	-0.0295***	(−)	0.0080	
	(0.0049)		(0.0070)	
XVoltoNOK	4.4040***	(+)	0.4965	
	(1.0426)		(0.6026)	
WorldTrade	0.4941***	(+)	-0.0065	
	(0.0554)		(0.1239)	
NorwayTrade	-0.1354***	(−)	-0.0145	
	(0.0075)		(0.0565)	
Diff	-0.0047***		-0.0057	
	(0.0015)		(0.0035)	
EUR	-0.4668***	(−)	-0.5462***	(−)
	(0.0922)		(0.1243)	
Constant	0.4179***			
	(0.1237)			
Observations	1,276		1,276	
Log-likelihood	-1,189.94		-1,088.97	
Pseudo R^2	0.15		0.22	

Notes: The dependent variable is the probability of currency j being chosen. Traders can choose from three currencies (PCI, LCI, and VCI), where we have normalized the coefficients of the country-specific variables for LCI. The top panel reports estimated coefficients of currency-specific variables, whereas the bottom panels report country-specific variables. ***, **, * denote significance at the 1, 5 or 10 percent level, respectively. Robust standard errors are reported in parentheses below the parameter estimates. All significant marginal effects are denoted by a (+) or (−), indicating the direction of the effect. The identified marginal effects are all significant at the 1 percent level, except the ones with a †, which are significant at the 5 percent level.

Table 8: Marginal Effects at a Representative Value for the Benchmark Specification

Year	Covariate	Currency	Canada	Germany	Greece	Italy	Japan	US
1998	**Currency Specific**							
	EUR	PCI	0.0283†	0.0411†***	0.0344†***	0.0437†***	0.0174†***	0.0341†***
			(0.0189)	(0.0057)	(0.0049)	(0.0056)	(0.0033)	(0.0066)
	Country Specific							
	CPI	PCI	-0.0060	-0.0106	-0.0086	-0.0112	-0.0041	-0.0084
			(0.0070)	(0.0075)	(0.0064)	(0.0080)	(0.0032)	(0.0060)
	CPIVol	PCI	-0.1143	-0.1673***	-0.1397***	-0.1777***	-0.0705***	-0.1385***
			(0.0756)	(0.0355)	(0.0294)	(0.0332)	(0.0110)	(0.0281)
	Diff	VCI	-0.0035***	-0.0027**	-0.0063**	-0.0037	-0.0082***	-0.0027**
			(0.0012)	(0.0014)	(0.0029)	(0.0022)	(0.0014)	(0.0012)
2006	**Currency Specific**							
	EUR	PCI	0.0282†	0.0340***	0.0423***	0.0427***	0.0286†***	0.0337†***
			(0.0181)	(0.0073)	(0.0058)	(0.0056)	(0.0041)	(0.0074)
	Country Specific							
	CPI	PCI	-0.0060	-0.0090	-0.0109	-0.0112	-0.0071	-0.0085
			(0.0074)	(0.0065)	(0.0080)	(0.0078)	(0.0052)	(0.0068)
	CPIVol	PCI	-0.1142	-0.1387***	-0.1724***	-0.1742***	-0.1162	-0.1373***
			(0.0744)	(0.0351)	(0.0342)	(0.0326)	(0.0201)	(0.0322)
	Diff	VCI	-0.0035***	-0.0013	-0.0042***	-0.0025***	-0.0071	-0.0022***
			(0.0014)	(0.0006)	(0.0015)	(0.0011)	(0.0018)	(0.0008)

Notes: Marginal effects for individual countries in the last quarter of 1998 and the last quarter of 2006 are reported. ***, **, * denote significance at the 1, 5 or 10 percent level, respectively. A † indicates a counterfactual outcome. Robust standard errors are reported in parentheses below the parameter estimates.

Appendix

A.1 Properties of Compositional Data

Compositional data with extreme values—i.e., observations that can attain values at the extremes of the $[0, 1]$ interval—can be defined by the following properties (cf. Aitchison, 1986).

(i) *Boundedness*: Each currency share is bounded within the closed unit interval; that is, $0 \leq s_{jnt} \leq 1$;

(ii) *Adding-up constraint*: All the currency shares for a given country n at a given quarter t add up to unity; that is, $\sum_{j=1}^{J} s_{jnt} = 1$; and

(iii) *Share correlation*: Two different currency shares $s_{jnt} = \frac{m_{jnt}}{\sum_j^J m_{jnt}}$ and $s_{knt} = \frac{m_{knt}}{\sum_j^J m_{jnt}}$ (for $j \neq k$) of the same country n and within the same time period t have the same denominator $\sum_j^J m_{jnt}$, implying that $\text{Cov}(s_{jnt}, s_{knt}) \neq 0$.

A.2 The Conditional CML Approach

Papke and Wooldridge (1996) propose a fractional logit approach to estimate a compositional data model with two alternative choices. They estimate the model using the method of quasi-maximum likelihood, which involves applying the Gauss-Newton procedure to the scores of the Bernoulli log-likelihood. We extend this approach by using more than two alternatives, thereby creating a multinomial version of the fractional logit. In addition, by using currency shares as dependent variable, we enter into the domain of compositional data (Appendix A.1). The typical fractional logit model type would only use "alternative-invariant" regressors, which are in our case country-specific variables. For conceptual purposes, we extend the method to "alternative-varying" regressors (i.e., currency-specific variables), which we call the *conditional* compositional multinomial logit approach. However, once we incorporate alternative-varying regressors, the likelihood does not have the simple scores as in the case of the multinomial extension of the fractional logit (see equations (A.3)–(A.4) of Appendix

A.3).[32] By including currency-specific variables, the model becomes much more complex. Instead of simply summing across the three currency groups, we distinguish 31 different currencies. Note that our currency set is time-varying; for example, the ECU and euro legacy currencies are dropped over time, whereas the euro is introduced.

With respect to inference, we treat each country n at quarter t as a single observation. However, as we split each real observation on our dependent variable into all the possible currency choices j, the number of observations expands, yielding a maximum of 32,944. As a result, roughly 50 percent of the dependent variable s_{jvnt} contains zeros. Because nonlinear least squares assigns too much weight to the zero observations, we maximize the log-likelihood function directly using a Quasi-Newton method, ignoring the zero shares in estimation and using the characteristics of the zero observations within the probabilities of the nonzero observations.

The CCML approach captures properties (i) and (ii) of Appendix A.1. However, the correlation property is not taken into account, because the logistic distribution assumes that observations are independently distributed, that is, the error terms ε_{jnt} and ε_{knt} of equation (5) for $j \neq k$ are assumed to be uncorrelated. The unobserved correlation might not only be within the unobserved mean, but also within the covariates itself. Unobserved correlation among alternatives has also been an issue in discrete choice logit models. The restricted substitution patterns implied by the logit model class has been called the independence of irrelevant alternatives (IIA) property.[33]

A.3 Asymptotic Equivalence of Predicted and Actual Shares

We know from maximum likelihood theory that the expected value of the score at the true parameter value $\boldsymbol{\theta}$ is zero:

$$\mathrm{E}_0[\mathbf{g}_{vnt}(\boldsymbol{\theta})] = \mathbf{0}, \tag{A.1}$$

[32] The simple compositional multinomial logit model (with country-specific variables only) can be computed using Stata's *pweight* command in combination with *mlogit*. We programmed the CCML approach using Matlab.

[33] Mixed logit models allow flexible correlation patterns among discrete alternatives (cf. Train, 2003), but are computationally very expensive to implement in the CCML context because of the already high dimensionality of the compositional data. Alternatively, we could have used the logistic-normal distribution. This type of model, however, does not allow extreme values, that is, shares can only lie within the open unit interval $(0, 1)$.

where

$$\mathbf{g}_{nt}(\boldsymbol{\theta}) = \frac{\partial \ln \mathrm{P}_{nt}(\boldsymbol{\theta})}{\partial \boldsymbol{\theta}}, \tag{A.2}$$

is the observation's score and $\boldsymbol{\theta}$ is the parameter vector. The observation's score with respect to the currency-specific vector $\boldsymbol{\alpha}$ is:

$$\frac{\partial \sum_{j=1}^{J} s_{jnt} \ln \hat{\mathrm{P}}_{jnt}}{\partial \boldsymbol{\alpha}} = \mathbf{Z}_t'(\boldsymbol{s}_{nt} - \hat{\mathrm{P}}_{nt}), \tag{A.3}$$

where both vectors $\boldsymbol{s}_{nt}$ and $\hat{\mathrm{P}}_{nt}$ have dimension $J \times 1$. The observation's score with respect to the country-specific vector $\boldsymbol{\beta}_v$ is:[34]

$$\frac{\partial \sum_{j=1}^{J} s_{jnt} \ln \hat{\mathrm{P}}_{jnt}}{\partial \boldsymbol{\beta}_v} = \mathbf{x}_{nt} \sum_{j=1}^{J_v} (s_{jnt} - \hat{\mathrm{P}}_{jnt}), \tag{A.4}$$

where J_v is the number of currencies in currency group v. Since $\mathbf{Z}_t$ and $\mathbf{x}_{nt}$ are non-zero, equality (A.1) only holds true when $s_{jnt} = \hat{\mathrm{P}}_{jnt}$ for all j.

A.4 The Robust Covariance Matrix

In constructing the covariance matrix, we adopt Papke and Wooldridge's (1996) line of reasoning. The parameters $\boldsymbol{\beta}_v$ and $\boldsymbol{\alpha}$ are consistent provided that

$$\mathrm{P}(s_{jnt} = 1 | \mathbf{x}_{nt}, \mathbf{Z}_t) = \frac{\exp(\mathbf{x}_{nt}'\boldsymbol{\beta}_v + \mathbf{z}_{jt}'\boldsymbol{\alpha} + \mathbf{d}_n\boldsymbol{\eta}_v)}{\sum_j^J \exp(\mathbf{x}_{nt}'\boldsymbol{\beta}_v + \mathbf{z}_{jt}'\boldsymbol{\alpha} + \mathbf{d}_n\boldsymbol{\eta}_v)}, \tag{A.5}$$

holds, satisfying $0 < \mathrm{P}(s_{jnt} = 1 | \mathbf{x}_{nt}, \mathbf{Z}_t) < 1$. However, $\mathrm{Var}(s_{jnt} | \mathbf{x}_{nt}\boldsymbol{\beta}_v, \mathbf{Z}_t\boldsymbol{\alpha})$ is unlikely to be constant when $0 \leq s_{jnt} \leq 1$. Papke and Wooldridge (1996) suggest to use an asymptotically robust covariance matrix:

$$\mathbf{V} = \mathbf{H^{-1}BH^{-1}}, \tag{A.6}$$

where $\mathbf{H^{-1}}$ is the inverse Hessian matrix and $\mathbf{B}$ is the average outer product or the variance of the scores, that is

$$\mathbf{B} = \frac{1}{NT} \sum_{n=1}^{N} \sum_{t=1}^{T} \mathbf{g}_{nt}(\hat{\boldsymbol{\theta}}) \mathbf{g}_{nt}(\hat{\boldsymbol{\theta}})'. \tag{A.7}$$

[34] The scores used by Papke and Wooldridge (1996) are a special case of equation (A.4) with $J = 2$ and no currency groups; that is, $\mathbf{x}_{nt}(s_{jnt} - \hat{\mathrm{P}}_{jnt})$.

Papke and Wooldridge (2008) have pointed out that in the case of panel data cluster-robust errors should be used to control for serial correlation. However, we only have 29 clusters, which is of insufficient size to use cluster-robust standard errors. Indeed, Cameron, Gelbach, and Miller (2010) argue that at least 50 clusters are needed for accurate inference. Instead, we follow Kézdi (2004), who finds that the sandwich robust estimator works well when the cross-sectional sample size is not especially large relative to the time-series dimension.

A.5 Average Marginal Effects

In nonlinear models like ours, the marginal effect does not equal the slope coefficients of the regression equation. The marginal effect measures the effect of a change in the regressor on the conditional probability that a currency is chosen with unit probability. There are different ways to measure marginal effects because they vary with the point of evaluation. The most common form is the marginal effect at the sample mean of the regressors,[35] which is a rough measure of the sign of the coefficient, but its magnitude is hardly interpretable. Alternatively, for policy analysis, using the *average* marginal effect is more meaningful. For currency-specific variables, the average marginal effect for currency group v is calculated by averaging over the change in the predicted probability across countries and time periods:[36]

$$\frac{1}{NT}\sum_{n=1}^{N}\sum_{t=1}^{T}\frac{\partial \hat{\mathrm{P}}_{vnt}}{\partial z_{knrt}}, \tag{A.8}$$

where $\hat{\mathrm{P}}_{vnt} = \sum_{j}^{J_v} \hat{\mathrm{P}}_{jnt}$ is the predicted group share summed across the predicted currency shares in the given group v with J_v currencies. In view of the large number of currencies, identifying every marginal effect with respect to all currencies would not be very meaningful. We therefore make inferences with respect to the currencies grouped according to $v = \{LCI, PCI, VCI\}$ as we have explained in Section 4. Equation (A.8) shows the change in the probability of choosing currency currency group v when the r-th currency-specific explanatory variable increases by one unit for currency group k does not change for the other

[35]This marginal effect can be computed in Stata by using the command *mfx*.

[36]Because of the convex nature of the exponential function, the average effect across agents differs from the effect for the average agent. Papke and Wooldridge (2008) also use average marginal effects to make inference about the magnitude of regressors. However, they call them average partial effects.

currency groups. For country-specific variables, we find

$$\frac{1}{NT}\sum_{n=1}^{N}\sum_{t=1}^{T}\frac{\partial\hat{\mathrm{P}}_{vnt}}{\partial x_{nrt}}, \tag{A.9}$$

which represents the change in the predicted share of currency group v when the r-th country-specific explanatory variable increases by one unit.

Because logit probabilities have closed-form solutions, the marginal effects for (A.8) can be stated explicitly as:

$$\frac{1}{NT}\sum_{n=1}^{N}\sum_{t=1}^{T}\hat{\mathrm{P}}_{vnt}(1-\hat{\mathrm{P}}_{knt})\hat{\beta}_r, \tag{A.10}$$

when $k = v$ and

$$\frac{1}{NT}\sum_{n=1}^{N}\sum_{t=1}^{T}(-\hat{\mathrm{P}}_{vnt})\hat{\mathrm{P}}_{knt}\hat{\beta}_r, \tag{A.11}$$

when $k \neq v$.

In the case of a dummy variable d, such as EUR_{jt} and $EuroControl_{jt}$, the average marginal effect for currency-specific variables is calculated as:

$$\frac{1}{NT}\sum_{n=1}^{N}\sum_{t=1}^{T}\left[\hat{\mathrm{P}}_{vnt}(\cdot|d=1)-\hat{\mathrm{P}}_{unt}(\cdot|d=0)\right], \tag{A.12}$$

when $u = v$ and

$$\frac{1}{NT}\sum_{n=1}^{N}\sum_{t=1}^{T}\left[\hat{\mathrm{P}}_{vnt}(\cdot|d=1)-\hat{\mathrm{P}}_{knt}(\cdot|d=0)\right], \tag{A.13}$$

when $k \neq v$. To arrive at the marginal effect of $EuroControl_{jt}$, we average across the transition period only.

The average marginal effects for the explanatory variables inform us directly about the average increase in the currency share, since the estimated probabilities are the predicted currency shares. To compute the marginal effect at a representative value of a covariate for a particular currency group (Table 8), we use the choice probabilities for the respective currency group, country, and time period. The marginal effects will be as displayed in (A.10)–(A.13), but without averaging across time periods and countries.

Table A.1: Norwegian Import and Currency Shares by Country, Averages for 1996–2006

Rank	Countries	Import share	Accumulated share: All countries	Accumulated share: OECD	PCI
1	Sweden*	15.423	15.423	15.423	45.405
2	Germany*	13.857	29.280	29.280	73.791
3	United Kingdom*	7.970	37.250	37.250	43.166
4	Denmark*	7.215	44.466	44.466	44.657
5	United States*	6.291	50.757	50.757	71.563
6	Netherlands*	4.501	55.258	55.258	55.048
7	France*	4.436	59.693	59.693	55.044
8	China	3.903	63.596	–	0.004
9	Italy*	3.756	67.352	63.449	57.087
10	Finland*	3.402	70.754	66.852	34.807
11	Japan*	3.377	74.132	70.229	22.155
12	Belgium*	2.276	76.407	72.505	44.587
13	Russia	2.236	78.643	–	0
14	Canada*	2.191	80.835	74.696	75.767
15	Spain*	1.612	82.447	76.308	54.864
16	Ireland*	1.453	83.900	77.761	16.159
17	Poland*	1.217	85.117	78.978	2.900
18	Switzerland*	1.216	86.333	80.194	44.957
19	Taiwan	0.942	87.275	–	0.177
20	Austria*	0.909	88.184	81.103	60.830
21	Brazil	0.794	88.979	–	0
22	Korea*	0.710	89.689	81.814	0
23	Czech Republic*	0.568	90.257	82.381	0.981
24	Portugal*	0.563	90.819	82.944	27.537
25	Singapore	0.546	91.365	–	50.736
26	Turkey*	0.511	91.876	83.454	0
27	Hong Kong	0.435	92.311	–	12.339
28	Malaysia	0.405	92.716	–	0.502
29	Hungary*	0.404	93.120	83.859	0
30	Suriname	0.402	93.523	–	0
31	Botswana	0.402	93.925	–	0
32	Estonia	0.377	94.301	–	7.536
33	Thailand	0.369	94.670	–	1.696
34	India	0.337	95.007	–	0.164
35	Jamaica	0.325	95.332	–	0

(*To be continued*)

Table A.1 (Continued)

Rank	Countries	Import share	Accumulated share		PCI
			All countries	OECD	
36	Lithuania	0.306	95.638	–	4.610
37	Iceland*	0.242	95.880	84.101	1.664
38	Romania	0.240	96.119	–	0
39	Indonesia	0.236	96.356	–	0
40	Australia*	0.216	96.572	84.317	8.211
41	Latvia	0.215	96.787	–	4.160
42	South Africa	0.206	96.993	–	1.539
43	Israel	0.171	97.164	–	0
44	Peru	0.161	97.325	–	0
45	Vietnam	0.152	97.477	–	0
46	Chile	0.149	97.626	–	0
47	Mexico*	0.128	97.753	84.444	0
48	Greece*	0.126	97.880	84.571	36.310
49	Colombia	0.124	98.004	–	0
50	Slovak Republic*	0.115	98.119	84.686	0
51	Pakistan	0.114	98.233	–	0.424
52	Argentina	0.114	98.347	–	0
53	Ukraine	0.107	98.454	–	0
54	Slovenia	0.105	98.559	–	0.001
55	Bangladesh	0.100	98.659	–	0
56	Tajikistan	0.100	98.759	–	0
57	Morocco	0.094	98.853	–	0
58	Costa Rica	0.077	98.929	–	0
59	Luxembourg*	0.074	99.003	–	35.913
60	Philippines	0.074	99.078	–	0
61	Venezuela	0.059	99.137	–	0
62	Uruguay	0.059	99.195	–	0
63	Saudi Arabia	0.043	99.238	–	0
64	New Zealand*	0.042	99.280	84.728	7.461

Notes: The first column with figures denotes Norway's (average) share in imports from the respective partner country. The second column presents the accumulated import share, whereas the third column gives the accumulated import share for OECD countries only (which are indicated by asterisks). PCI refers to the share of partner currencies used in invoicing of Norwegian imports.

Table A.2: Data Description and Sources

Variable	Description	Primary Source
LCI_{nt}	Fraction of Norwegian imports from partner (or producer) country n that is invoiced in the Norwegian Krone.	Calculated based on customs data provided by Statistics Norway
PCI_{nt}	Fraction of Norwegian imports from partner country n that is invoiced in the partner currency.	Calculated based on customs data provided by Statistics Norway
VCI_{nt}	Fraction of Norwegian imports from partner country n that is invoiced in third currencies.	Calculated based on customs data provided by Statistics Norway
$WorldTrade_{nt}$	World trade share of country n at time t (in percent). Defined as the sum of the value of goods exports and imports of country n divided by the sum of the value of world exports and imports.	OECD trade data http://www.oecd.org/statsportal/
$WorldTrade_{jt}$	World trade share of the country or countries using currency j at time t (in percent). Defined as the sum of the value of goods exports and imports of country n divided by the sum of the value of world exports and imports.	OECD trade data http://www.oecd.org/statsportal/
$NorwayTrade_{nt}$	Goods trade share of country n with Norway at time t (in percent). Defined as the sum of country n's value of exports to and imports from Norway divided by the sum of Norway's goods exports and imports.	Statistics Norway http://www.ssb.no/en/

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Table A.2: Data Description and Sources (Continued)

Variable	Description	Primary Source
$Diff_{nt}$	Share of differentiated goods in Norwegian imports from country n in year t (in percent). Calculated as the sum of imported goods that are classified (based on SITC 4) to be differentiated by the conservative specification of the Rauch-Index (cf. Rauch, 1999) divided by total value of Norwegian imports in that period.	Statistics Norway http://www.ssb.no/en/
Ref_{nt}	Share of referenced-priced goods in Norwegian imports from country n in year t (in percent). Calculated as the sum of imported goods that are classified (based on SITC 4) to be referenced priced by the conservative specification of the Rauch-Index (cf. Rauch, 1999) divided by total value of Norwegian imports in that period.	Statistics Norway http://www.ssb.no/en/
CPI_{nt}	Expected inflation rate of partner country n at time t (in percent). Calculated as a 4-period moving average of the consumer price index (CPI) of country n.	IMF's IFS http://www.imfstatistics.org/imf/
CPI_{jt}	Expected inflation rate of the countries using currency j at time t (in percent). Calculated as a 4-period moving average of the average CPI of the countries using currency j.	IMF's IFS http://www.imfstatistics.org/imf/
$CPIVol_{nt}$	Expected inflation volatility of partner country n a time t. Calculated as the standard deviation of the CPI of the four preceding quarters.	IMF's IFS http://www.imfstatistics.org/imf/
$CPIVol_{jt}$	Expected inflation volatility of partner or partner countries using currency j at time (in percent). Calculated as the standard deviation of the CPI of the four preceding quarters.	IMF's IFS http://www.imfstatistics.org/imf/
$XVoltoNOK_{nt}$	Expected volatility of the exchange rate of the Norwegian Krone with respect to the currency of country n time t. Calculated as the coefficient of variation of the four preceding quarters.	IMF's IFS http://www.imfstatistics.org/imf/

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Table A.2: Data Description and Sources (Continued)

Variable	Description	Primary Source
$XVoltoNOK_{jt}$	Expected volatility of the exchange rate of the Norwegian Krone with respect to the chosen currency j at time t. Calculated as the coefficient of variation of the four preceding quarters.	IMF's IFS http://www.imfstatistics.org/imf/
$XVoltoProd_{jnt}$	Expected volatility of the exchange rate of the producer currency with respect to the chosen currency j at time t. Calculated as the coefficient of variation of the four preceding quarters.	IMF's IFS http://www.imfstatistics.org/imf/
$SizeFX_{nt}$	Depth of the foreign exchange market of the currency of country n at time t.	BIS http://www.bis.org/statistics
$SizeFX_{jt}$	Depth of the foreign exchange market of currency j at time t. Calculated based on the *Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity* conducted by the Bank of International Settlements (BIS) The survey reports the currency distribution of foreign exchange market turnover during a given day. A moving average (of three years) of fractions of the individual currencies is used to determine the foreign exchange market depth. Surveys relevant to our study were conducted in 1995, 1998, 2001, 2004, and 2007.	BIS http://www.bis.org/statistics
EUR_{nt}	Dummy variable taking on a value of one if the partner country n is part of the eurozone.	ECB http://www.ecb.int/
EUR_{jt}	Dummy variable taking on a value of one if the chosen currency j is part of the eurozone or the euro itself.	ECB http://www.ecb.int/
$EuroControl_{jt}$	Dummy variable taking on a value of one if the chosen currency j is one of the legacy currencies between January 1, 1999 and December 31, 2001.	ECB http://www.ecb.int/

Table A.3: Descriptive Statistics

	Observations $N \times T$	Mean	Standard deviation	Min	Max
LCI_{nt}	1,276	0.3543	0.1577	0.0149	0.7995
PCI_{nt}	1,276	0.3123	0.2724	0	0.9260
VCI_{nt}	1,276	0.3333	0.2399	0.0092	0.9397
$WorldTrade_{nt}$	1,276	0.7273	0.8840	0.0082	4.4337
$WorldTrade_{jt}$	1,276	0.8362	1.1384	0.0082	5.4755
$NorwayTrade_{nt}$	1,276	2.9284	3.6811	0.0293	15.5398
$Diff_{nt}$	1,276	74.1243	20.7023	11.7460	99.0010
Ref_{nt}	1,276	19.2217	15.2730	0.6714	79.2649
CPI_{nt}	1,276	5.1098	11.2552	-1.0076	93.7205
CPI_{jt}	1,276	5.4667	11.8765	-1.0076	93.7205
$CPIVol_{nt}$	1,276	0.7962	1.6186	0.0331	21.5883
$CPIVol_{jt}$	1,276	0.8884	1.6972	0.0331	21.5883
$XVoltoNOK_{nt}$	1,276	0.0304	0.0297	0.0015	0.3326
$XVoltoNOK_{jt}$	1,276	0.0300	0.0317	0	0.3326
$XVoltoProd_{jt}$	1,276	0.0367	0.0408	0	0.3684
$SizeFX_{nt}$	1,276	8.3405	10.4873	0.0100	45.1500
$SizeFX_{jt}$	1,276	3.6759	8.9979	0	45.1500
EUR_{nt}	1,276	0.2955	0.4564	0	1.0000
EUR_{jt}	1,276	0.1585	0.3652	0	1.0000
$EuroControl_{jt}$	1,276	0.1303	0.3366	0	1.0000

Notes: The variables are described in Table A.2. To conserve on space, we only report the currency shares for the three currency groups. For estimation purposes, we create $N \times T \times J^t$ observations, which yields a maximum of 32,944 observations.

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